AD-A040 344 CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAI--ETC F/G 13/13
ENERGY UTILIZATION INDEX METHOD FOR PREDICTING BUILDING ENERGY --ETC(U)
MAY 77 L M WINDINGLAND, D C HITTLE DACA-23-76-C-0001
UNCLASSIFIED CERL-IR-E-105-VOL-2 NL

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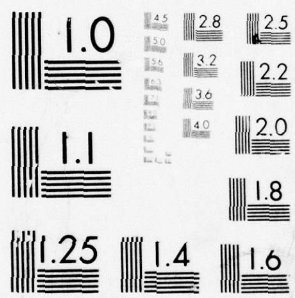

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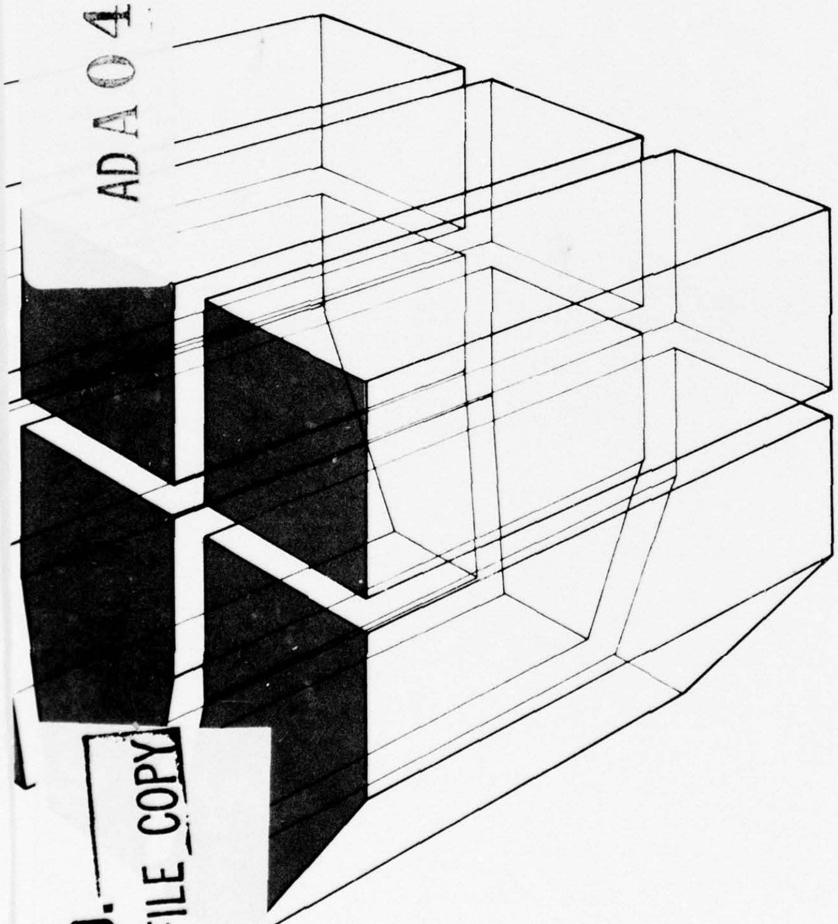
May 1977

ENERGY UTILIZATION INDEX METHOD FOR PREDICTING BUILDING ENERGY USE
VOLUME II: PROPOSED SUPPLEMENT TO TB ENG 529



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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 14 CERL-IR-E-105-Vol-2	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 9
4. TITLE (and Subtitle) 6 ENERGY UTILIZATION INDEX METHOD FOR PREDICTING BUILDING ENERGY USE. VOLUME II. PROPOSED SUPPLEMENT TO TB ENG 529		5. TYPE OF REPORT & PERIOD COVERED INTERIM rept. 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 L. M. Windingland, Barry K. Hinkle D. C. Hittle, James E. Piper		8. CONTRACT OR GRANT NUMBER(s) 15 DACA-23-76-C-0001
9. PERFORMING ORGANIZATION NAME AND ADDRESS CONSTRUCTION ENGINEERING RESEARCH LABORATORY P.O. Box 4005 Champaign, Illinois 61820		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 12 167p.
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 11 May 1977 13. NUMBER OF PAGES 166
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) 16 4A762719AT41		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

DDC-A039913

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Copies are obtainable from National Technical Information Service, Springfield, VA 22151

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

fuel consumption
energy use
energy conservation

A039913

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes development of the Energy Utilization Index (EUI) method for manually calculating monthly and annual energy consumption for buildings on military installations. The method uses basic building parameters such as U-factors, dimensions, occupancy, type of HVAC equipment, and average monthly weather conditions to arrive at a prediction for a building's monthly and annual energy use. Procedures for aggregating individual building consumption data into facility and → next

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installation consumption predictions are provided. The method for correcting the predictions to account for actual weather conditions is also described.

Volume I describes the development of the EUI method, tells how the method is used, and compares predictions generated by the method with actual consumption data. A comparison of ± 4 percent was shown for one building type.

Volume II is a proposed supplement to TB ENG 529, *Repairs and Utilities, Utilities Utilization, Targets and Evaluations* (13 Mar 61), based on the EUI method. The information is intended to supplement Chapters 2 and 3 of TB ENG 529 and provides Facilities Engineering personnel with a refined method for predicting energy use in support of budget preparation, command reporting requirements, and the evaluation of energy conservation alternatives.

FOREWORD

This study was performed for the Directorate of Facilities Engineering, Office of the Chief of Engineers (OCE), as part of RDT&E program 6027.19A, Project 4A762719AT41, "Design, Construction, and Operations and Maintenance Technology for Military Facilities"; Task T6, "Energy Systems"; Work Unit 009, "Energy Utilization of Mechanical Systems." The OCE Technical Monitor is Mr. James Walton.

The work was performed under Contract No. DACA-23-76-C-0001 by Hittman Associates, Inc., Columbia, MD, for the Energy Systems Branch, Energy and Power Division of the U.S. Army Construction Engineering Research Laboratory (CERL), Champaign, IL. Mr. Douglas C. Hittle and Mr. Larry M. Windingland were the CERL Principal Investigators. Dr. Donald J. Leverenz is Chief of the Energy Systems Branch and Mr. Richard G. Donaghy is Chief of the Energy and Power Division.

COL J. E. Hays is Commander and Director of CERL. Dr. L. R. Shaffer is Technical Director.

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I. GENERAL

This supplement to TB ENG 259 provides instructions for computing monthly heating and cooling fuel consumptions as well as for forecasting fuel use for the following items:

- Lighting
- Electric equipment and appliances
- Cooking
- Hot water
- Laundry
- Cold storage
- Additional energy users

Though the instructions given here are for five specific building types (single-family, town house, barracks, administrative/office, and commissary), the same procedures can also be used for other building types with some similarity in utilization activity level to one of the five types presented here.

In addition to computation of fuel use for the items mentioned above, the effect of energy conservation measures can be determined by employing the provided instructions.

The user of this manual must supply data pertinent to the building being investigated. Such data includes:

Monthly heating degree days

Monthly cooling degree days

Monthly average wind velocity

Exterior wall composition

Exterior wall areas

Window area

Number of doors and windows

Existence of storm doors or windows

Underground floor and wall composition

Floor areas

Inside set-point temperatures

Mechanical ventilation rate

Occupancy level

Boiler/furnace efficiency

Air conditioner chiller EER

Distribution efficiency

If portions of this data are unknown or unavailable, the default values or the values from the examples presented in the text may be used as an approximation. However, the accuracy of the results depends upon the information supplied by the user.

The figures included in this manual are included at the end of the manual and are numbered according to the building type in the following manner;

A- Single-family residence

B- Town house

C- Barracks

D- Administration/office

E- Commissary

For example, Figure 1-A corresponds to the building envelope heat loss for a single-family residence.

Although the procedures presented here render energy use by month, annual energy use can be obtained by addition of monthly values.

All definitions stated in the TB ENG 259 are applicable in this supplement unless otherwise stated.

Partial examples are provided throughout the text, and a complete example is provided in Appendix A.

II. HEATING

A. Definitions

1. Building Envelope Area. The total area of all building surfaces (walls, roofs, windows, floors, and doors) which are exposed to the outside air. This includes floors over crawl spaces, but does not include floors over basements or on slabs-on-grade; nor does it include walls and floors below ground level.

2. Equivalent U Value. The area weighted average thermal conductance for the entire building exposed envelope area.

B. Building Envelope Heating Load

1. Using the number of monthly heating degree days for a given month determine QH_1 from Figure 1. For values beyond the range of the figure, use the end point values. Example: for a single-family residence during a 1000 heating degree day month, from Figure 1-A, $QH_1 = 3.1 \times 10^4$ Btu/degree day.

2. Determine the building envelope equivalent U value as follows

   (a) Calculate the areas of each surface type in the building envelope area.

   (b) Multiply each surface area by its proper U value from ASHRAE tables (Ref. 1).

   (c) Add the products of the structural envelope areas and U value and divide by the total envelope area to obtain the building envelope equivalent U value.

Example:

Exterior Surface	Area (sq ft)	U Value (Btu/hr-sq ft-°F)	Area X U Value
A	1200	0.20	240
B	300	0.15	45
C	250	0.25	63
X	1000	0.30	300
Y	300	0.40	120
Z	40	1.05	42
	3090		810

envelope equivalent U value = $\frac{810}{3090}$ = 0.262 Btu/hr-sq ft-°F.

3. Determine the conduction correlation factor, CH_1, from Figure 2. For values beyond the range of the figure, extend the curve linearly. Example: for a single-family residence with an envelope equivalent U value of 0.262, from Figure 2-A, $CH_1 = 0.98$.

4. Using the number of heating degree days for a given month, determine the set-point correlation factor, FH_1, from Figure 3. For values beyond the range of the figure, use the end point values. Example: for a single-family residence during a 1000 heating degree day month, from Figure 3-A, $FH_1 = 0.035$.

5. The monthly building envelope heating load can be determined from the following equation.

$$QH_{env} = (CON)(QH_1)(HDD)(CH_1)(A_{total})[1 + FH_1(T-72)]$$

where,

CON = 2.246×10^{-4} for a single-family residence
= 5.296×10^{-4} for a town house
= 0.209×10^{-4} for a barrack
= 0.850×10^{-4} for an administration building
= 0.425×10^{-4} for a commissary
QH_1 = Building envelope heating load from Figure 1
HDD = Monthly heating degree days
CH_1 = Conduction correlation factor from Figure 2
A_{total} = Building envelope area sq ft
FH_1 = Set-point correlation factor from Figure 3
T = Indoor set-point temperature, °F

Example: A single-family residence has an envelope area of 3090 sq ft, an envelope equivalent U value of 0.262, and an indoor set-point temperature of 70°F during a 1000 heating degree day month. From Figure 1-A, $QH_1 = 31000$ Btu. From Figure A-2, $CH_1 = 0.98$. From Figure 3-A, $FH_1 = 0.035$. Then,

$$QH_{env} = 2.246\times10^{-4}\ (31000)\ (1000)(0.98)$$

$$(3090)\ [1+0.035(70-72)]$$

$$= 19{,}600{,}000 \text{ Btu/month}$$

C. Infiltration/Mechanical Ventilation Heating Load

1. For single-family and town house residences, determine the infiltration rate as follows:

(a) Calculate the infiltration coefficient, A, from the following equation.

$$A = 0.25\ (N_D)\ (S_1) + 7.7 \times 10^{-3}\ (A_W)\ (S_2)$$

where,

N_D = Number of doors, not including sliding glass doors

S_1 = 0.67 with storm doors

S_1 = 1.0 without storm doors

A_W = Total window area including sliding glass doors, sq ft

S_2 = 0.67 with storm windows

S_2 = 1.0 without storm windows

Example: A single-family residence has two doors and 250 sq ft of windows, without storm doors/windows. Then,

$$A = 0.25\ (2)\ (1.0) + 7.7 \times 10^{-3}\ (250)\ (1.0)$$
$$= 2.43$$

(b) Obtain the average wind velocity, V, for the month from available weather data. If the average velocity is not known, use V=8.0 mph.

(c) Calculate the infiltration rate, I, from the following equation.

$$I = [0.25 + (0.037)\ (A)\ (V)]\ \frac{VOLUME}{60}$$

where,

A = Infiltration coefficient

V = Average wind velocity, mph

VOLUME = Volume of building, cu ft

Example: A single-family residence with an infiltration coefficient of 2.43 has a total volume of 14,000 cubic feet. For an average wind velocity of 8 mph, the infiltration rate is:

$$I = [0.25 + (0.037)\ (2.43)\ (8)]\ \frac{14,000}{60}$$

$$= 226 \text{ cfm}$$

2. For barracks and administration buildings that use outside air, I=0. For barracks that use outside air, use $V_r=0.30 \times 10^{-6}$ cfm/sq ft floor area. For administration buildings that use outside air, use $V_r=0.66 \times 10^{-6}$ cfm/sq ft floor area.

3. For commissaries, calculate the infiltration rate from the following equation.

$$I = (0.35)\ (N_C)$$

where,

N_C = Number of customers in the commissary per day

4. Calculate the infiltration/ventilation heating load as follows.

   (a) Obtain the outside air intake rate, V_r, in cfm, for the building being evaluated. If there is no outside air used, then $V_r = 0$. If V_r is not known, use $V_r = (0.15)(\text{floor area})$.

   (b) Using the number of heating degree days per month, determine the net infiltration heating load per cfm of infiltration, QH_2, from Figure 4. For values beyond the range of the figure, extend the curve linearly.

   (c) From Figure 5, determine the temperature set-point correlation factor, FH_2, for the corresponding number of monthly heating degree days. For values beyond the range of the figure, use the end-point values.

   (d) Calculate the infiltration heating load from the following equation.

$$Q_{inf} = (I + V_r)\ (QH_2)\ [1 + FH_2\ (T - 72)]$$

where,

I = Infiltration rate, cfm
V_r = Mechanical ventilation rate, cfm
QH_2 = Net infiltration heating load from Figure 4, Btu/cfm
FH_2 = Temperature set-point correlation factor from Figure 5
T = Indoor set-point temperature, °F

Example: A single-family residence heated to 70°F during a 1000 heating degree day month, has an infiltration rate of 226 cfm and no mechanical ventilation. From Figure 4-A, QH_2=33,500 Btu/cfm. From Figure 5-A, FH_2=0.0375. Then,

$$Q_{inf} = (226+0)\ (33{,}500)\ [1+0.0375\ (70-72)]$$
$$= 7{,}000{,}000 \text{ Btu/month}$$

5. If a building system operates for some time with no outside air intake (i.e., no mechanical ventilation), and the air handling system operates with 100 percent recycled air, then Q_{inf} is modified by the following expression.

$$QH_{inf} = (QH_{inf})_{24\ hr} \left[1 - \frac{X}{24}\right]$$

where,

$(QH_{inf})_{24\ hr}$ = Infiltration heating load as calculated in Section II-C

X = Number of hours per day system operates without using outside air

D. Solar Radiation Heat Gain

1. Determine the solar radiation coefficient, CR, as follows.

(a) For the latitude of the given location, determine the CR value from Figure 6, where

(b) CR_2 corresponds to the winter heating months of November, December, January, and February; and

(c) CR_4 corresponds to the spring/fall heating months of March, April, May, September, and October. For values beyond the range of the figure, use the end-point values.

2. Determine the incident radiation, IR, From Table 1-A for the given month and location. Use data from Table 1 for the city which is closest to the Army facility being evaluated.

3. Calculate the solar radiation heat gain, QH_{rad}, from the following equation.

$$QH_{rad} = 3.687\ (N_{days})(IR)(A_W)(CR)$$

where,

N_{days} = Number of days in the month

IR = Solar radiation coefficient from Table 1

A_W = Total window area, sq ft

CR = Value of CR_2, or CR_4 (depending on month) from Figure 6

Example: A Chicago single-family residence has 400 square feet of window area. For January, from Figure 6-A, CR=0.305. From Table 1-A, IR=96.

Then,

$$\begin{aligned} QH_{rad} &= 3.687\ (31)(96)(400)(0.305) \\ &= 1{,}340{,}000 \text{ Btu/month} \end{aligned}$$

E. Underground Floors/Walls

1. Determine the heating load due to underground floors and/or walls, QH_{floor}, as follows.

(a) Determine the correlation factor, CH_F, for the corresponding number of monthly heating degree days from Figure 7. For values beyond the range of the figure, extend the curve linearly.

Table 1-A. AVERAGE DAILY TERRESTRIAL SOLAR ENERGY RECEIVED ON A HORIZONTAL SURFACE (1γ/DAY)

LOCATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Annette, Ak	63	113	231	360	457	466	481	352	266	122	59	40	251
Barrow, Ak	0	38	180	380	513	528	429	255	115	41	0	0	206
Bethel, Ak	38	108	282	444	457	454	376	252	202	115	44	22	233
Fairbanks, Ak	16	71	213	376	461	504	434	317	180	82	26	6	224
Matanuska, Ak	32	92	242	356	436	462	409	314	198	100	38	15	224
Little Rock, Ar	188	260	353	446	523	559	556	518	439	343	244	187	385
Page, Az	294	367	516	618	695	707	680	596	516	402	310	243	495
Phoenix, Az	301	409	526	638	724	739	658	613	566	449	344	281	520
Tucson, Az	315	391	540	655	729	699	626	588	570	442	356	305	518
Yuma, Az	305	401	517	633	703	705	652	587	530	442	330	271	506
Davis, Ca	158	256	402	528	636	702	690	611	498	348	216	148	433
Eureka, Ca	146	194	306	399	471	494	462	406	342	249	159	131	313
Fresno, Ca	186	296	438	545	637	697	668	606	503	375	241	160	446
Inyokern, Ca	312	419	578	701	789	836	784	738	648	484	366	295	579
La Jolla, Ca	244	302	397	457	506	487	497	464	339	320	277	221	380
Los Angeles-WBAS, Ca	248	331	470	515	572	596	641	581	503	373	289	241	447
Los Angeles-WBO, Ca	243	327	436	483	555	584	651	581	500	362	281	234	436
Pasadena, Ca	251	333	439	509	569	580	634	599	482	366	271	236	439
Riverside, Ca	271	362	468	526	608	666	652	603	521	400	309	260	470
San Mateo, Ca	195	282	409	512	577	598	540	477	425	332	229	176	396
Santa Maria, Ca	263	346	482	552	635	694	680	613	524	419	313	252	481
Soda Springs, Ca	223	316	374	551	615	691	760	681	510	357	248	182	459
Boulder, Co	201	268	401	460	460	525	520	439	412	310	222	182	367
Grand Junction, Co	227	324	434	546	615	708	676	595	514	373	260	212	457
Grand Lake, Co	212	313	423	512	552	632	600	505	476	361	234	184	416
Washington, DC	158	231	322	398	467	510	496	440	364	278	192	141	333
Aplachicola, Fl	298	367	441	535	603	578	529	511	456	413	332	262	444
Belle Isle, Fl	297	330	412	463	483	464	488	461	400	366	313	291	397
Gainesville, Fl	278	367	445	539	536	544	520	508	444	368	318	254	431
Jacksonville, Fl	267	346	423	514	556	525	522	476	383	331	274	230	404
Key West, Fl	327	410	490	572	579	543	534	501	445	394	332	292	452
Miami, Fl	343	416	491	544	552	531	537	508	447	389	354	319	453
Pensacola, Fl	250	321	405	509	562	568	537	509	430	394	278	224	416
Tallahassee, Fl	274	311	423	483	548	476	544	537	424	353	364	260	416
Tampa, Fl	327	391	474	539	596	574	534	494	454	400	356	300	453
Atlanta, Ga	228	284	377	484	535	554	538	502	412	350	265	201	394
Griffin, Ga	238	302	388	519	577	580	559	523	437	372	288	210	416
Honolulu, Hi	363	422	516	559	617	615	615	612	573	507	426	371	516
Pearl Harbor, Hi	355	404	438	536	577	562	610	575	536	466	393	349	483
Boise, Id	138	236	342	485	585	636	670	576	460	301	182	124	395
Twin Falls, Id	163	240	355	462	562	592	602	540	432	286	176	131	378

Source: Determining the Availability of Solar Energy Within the Contiguous United States, EI & I Associates, 1975.

Table 1-A.(cont.). AVERAGE DAILY TERRESTRIAL SOLAR ENERGY RECEIVED ON A HORIZONTAL SURFACE (1Y/DAY)

LOCATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Chicago, Il	96	147	227	331	424	458	473	403	313	207	120	76	273
Lemont, Il	171	232	326	390	497	553	527	486	384	265	157	131	343
Moline, Il	159	220	317	402	493	558	565	498	407	290	176	134	352
Indianapolis, In	147	214	312	393	491	547	542	486	405	293	176	130	345
Ames, Ia	174	253	326	403	480	541	436	460	367	274	187	143	345
Dodge City, Ks	255	316	418	528	568	650	642	592	493	380	285	234	447
Kansas City, Ks	182	251	342	441	522	589	579	525	426	327	215	164	380
Manhattan, Ks	192	264	345	433	527	551	531	526	410	292	227	156	371
Topeka, Ks	192	249	337	430	505	554	552	512	424	320	214	165	371
Lexington, Ky	172	263	357	480	581	628	617	563	494	357	245	175	411
Louisville, Ky	164	231	325	420	515	560	550	498	408	303	190	150	360
Lake Charles, La	239	304	396	483	554	582	521	506	448	402	296	232	414
New Orleans, La	237	296	393	479	539	549	502	491	418	389	269	220	399
Shreveport, La	232	292	384	446	558	557	578	528	414	354	254	205	400
Blue Hill, Ma	153	228	319	389	469	510	502	449	354	266	162	135	328
Boston, Ma	139	198	293	364	472	499	496	425	341	238	145	119	311
Cambridge, Ma	153	235	323	400	420	476	482	464	367	253	164	124	322
East Wareham, Ma	140	218	305	385	452	508	495	436	365	258	163	140	322
Lynn, Ma	118	209	300	394	454	549	528	432	341	241	135	107	317
Annapolis, Md	175	243	340	419	488	557	542	469	383	294	189	155	355
Silver Hill, Md	182	244	340	438	513	555	516	459	397	295	202	163	359
Caribou, Me	133	231	364	400	476	470	508	448	336	212	111	107	316
Portland, Me	157	237	359	406	513	541	561	482	383	273	157	138	351
East Lansing, Mi	121	210	309	359	483	547	540	466	373	255	136	108	311
Sault Ste Marie, Mi	130	225	356	416	523	557	573	472	322	216	105	96	333
St. Cloud, Mn	170	251	366	423	499	541	555	491	360	241	146	123	348
Columbia, Mo	173	251	340	434	530	574	574	522	453	322	225	158	380
Glasgow, Mt	154	258	385	466	568	605	645	531	410	267	154	116	388
Great Falls, Mt	140	232	366	434	528	583	639	532	407	264	154	112	366
Summit, Mt	122	162	268	414	462	493	560	510	354	216	102	76	312
Lincoln, Ne	188	259	350	416	494	544	568	484	396	296	199	159	363
North Omaha, Ne	193	229	365	463	516	546	568	519	410	298	204	170	379
North Platte, Ne	200	266	358	475	522	599	598	540	432	322	220	178	393
Bismarck, N.D.	157	250	356	447	550	590	617	516	390	272	161	124	369
Cape Hatteras, NC	244	317	432	571	635	645	629	557	472	361	284	216	447
Greensboro, NC	200	276	354	469	531	564	544	485	406	322	243	197	383
Sea Brook, NJ	157	227	318	403	478	522	518	457	385	285	192	139	340
Trenton, NJ	173	214	343	424	491	546	540	469	389	294	195	155	355
Albuquerque, NM	303	386	511	618	686	726	683	626	554	438	334	276	512
Ely, Nv	238	333	464	564	624	708	648	608	519	393	287	220	467
Las Vegas, Nv	277	384	519	621	702	748	675	627	551	429	318	258	509
Reno, Nv	234	324	449	592	664	714	707	646	532	395	277	209	479
Ithaca, NY	116	194	272	334	440	501	515	453	346	231	120	96	302

Table 1-A. (cont.). AVERAGE DAILY TERRESTRIAL SOLAR ENERGY RECEIVED ON A HORIZONTAL SURFACE (LY/DAY)

LOCATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
New York, NY	146	210	312	378	455	526	518	492	361	262	160	128	324
Sayville, NY	160	249	335	415	494	565	543	462	385	289	186	142	352
Schenectady, NY	130	200	273	338	413	448	441	397	299	218	128	104	282
Upton, NY	155	232	339	428	502	573	543	475	391	293	182	146	355
Cleveland, Oh	125	183	303	286	502	562	562	494	278	289	141	115	320
Columbus, Oh	128	200	297	391	471	562	542	477	422	286	176	129	340
Put in Bay, Oh	126	204	302	386	468	544	561	487	382	275	144	109	332
Oklahoma City, Ok	255	317	407	498	540	623	610	588	484	379	284	237	435
Stillwater, Ok	205	289	390	454	504	600	596	545	455	354	269	209	405
Astoria, Or	90	162	270	375	492	469	539	461	354	209	111	79	301
Medford, Or	116	169	216	317	429	491	497	409	339	207	118	77	282
Philadelphia, Pa	175	242	347	425	493	554	538	465	388	293	191	152	355
State College, Pa	139	202	297	373	467	544	528	454	361	275	155	120	335
Newport, RI	115	231	330	395	489	538	517	449	380	273	175	141	339
Charleston, SC	250	308	393	517	553	556	523	495	417	349	281	228	406
Rapid City, SD	183	277	400	482	532	585	590	541	435	315	204	158	392
Oak Ridge, Tn	161	239	331	450	518	551	526	478	416	318	213	163	364
Memphis, Tn	192	267	359	470	554	589	583	535	442	354	238	184	397
Nashville, Tn	163	240	329	450	517	567	553	494	428	327	217	161	370
Brownsville, Tx	287	336	402	458	556	604	619	555	465	406	284	253	435
Corpus Cristi, Tx	262	330	413	474	561	604	629	558	470	408	285	240	436
Dallas, Tx	231	307	394	454	521	595	588	538	458	363	261	221	411
El Paso, Tx	331	432	549	655	715	730	670	639	575	462	367	313	536
Fort Worth, Tx	250	320	427	488	562	651	613	593	503	403	306	245	477
Midland, Tx	283	258	476	550	611	617	608	574	552	396	325	275	466
San Antonio, Tx	279	347	417	455	541	612	639	585	493	398	295	256	442
Flaming Gorge, Ut	238	298	443	522	565	650	599	538	425	352	262	215	426
Salt Lake City, Ut	163	256	354	479	570	621	620	551	446	316	204	146	394
Norfolk, Va	208	270	372	477	540	572	550	481	398	310	223	184	382
Burlington, Vt	129	198	300	367	495	530	532	455	343	231	124	103	317
Friday Harbor, Wa	87	157	274	418	514	578	586	507	351	194	102	75	320
Pullman, Wa	111	205	304	462	558	653	699	562	410	245	146	96	372
Prosser, Wa	117	222	351	521	616	680	707	604	458	274	136	100	399
Seattle, Wa	70	124	244	360	446	471	501	431	310	174	90	59	273
Spokane, Wa	119	204	321	474	563	596	665	556	404	225	131	75	361
Tacoma, Wa	75	139	265	403	503	511	566	452	324	188	104	64	300
Greenbay, Wi	137	210	312	385	490	542	539	462	353	240	139	110	327
Madison, Wi	148	220	313	394	466	514	531	452	348	241	145	115	324
Milwaukee, Wi	149	210	312	403	509	565	562	485	392	267	161	120	345
Lander, Wy	226	324	452	548	587	678	651	586	472	354	239	196	443
Laramie, Wy	216	295	424	508	554	643	606	536	438	324	229	186	408

(b) Determine the underground floor U value, U_f, from Reference 1, or use $U_f = 0.1$ for slab on grade, or $U_f = 0.2$ for floors over unheated basements.

(c) Determine the underground wall U value U_w, from Reference 1, or use $U_w = 0.15$.

(d) Determine the average monthly temperature for the city closest to the Army post from Table 1-B. Using this value, determine the monthly ground temperature from Figure 19.

Calculate the load due to underground floors/walls from the following equation.

$$QH_{floor} = (CH_F)\ [(A_f)(u_f)+(A_w)(U_w)]\ (T-T_g)$$

where,

CH_F = Correlation factor from Figure 7

A_f = Total underground floor area, sq ft

U_f = Floor U Value from Reference 1, Btu/hr-sq ft-°F

A_w = Total underground wall area, sq ft

U_w = Wall U value from Reference 1, Btu/hr-sq ft-°F

T = Inside set-point temperature, °F

T_g = Ground temperature from Reference 2, °F

Example: A single-family residence has 1100 square feet of floor area on a slab and 70°F indoor set-point temperature. During a 1000 heating degree day month, the ground temperature is 55°F. From Figure 7, CH_F = 700. From Reference 1, U_f=0.1. Then,

$$\begin{aligned} QH_{floor} &= (700)[(1100)(0.1)+(0)(0)](70-55) \\ &= 1{,}050{,}000 \text{ Btu/month} \end{aligned}$$

Table 1-B. AVERAGE MONTHLY TEMPERATURE

City	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	ANNUAL
Albany	22.7*	23.7*	33.0*	46.2*	57.9*	67.3*	72.1*	70.0*	61.6*	50.8*	39.1*	26.5*	47.6*
Albuquerque	35.0	39.9	45.8	55.7	65.1	74.9	78.5	76.2	70.0	58.0	43.6	37.0	56.6
Atlanta	44.7	46.1	51.4	60.2	69.1	76.6	78.9	78.2	73.1	62.4	51.2	44.8	61.4
Baltimore	34.8	35.7	43.1	54.2	64.4	72.5	76.8	75.0	68.1	57.0	45.5	35.8	55.2
Bismarck	9.9	13.5	26.2	43.5	55.9	64.5	71.7	69.3	58.7	46.7	28.9	17.8	42.2
Boise	29.1	34.5	41.7	50.4	58.2	65.8	75.2	72.1	62.7	51.6	38.6	32.2	51.0
Boston	29.9	30.3	37.7	47.9	58.8	67.8	73.7	71.7	65.3	55.0	44.9	33.3	51.4
Buffalo	24.5	24.1	31.5	43.5	54.8	64.8	69.8	68.4	61.4	50.8	39.1	27.7	46.7
Burlington, Vt.	16.2	17.4	26.7	41.2	53.8	64.2	69.0	66.7	58.4	47.6	35.3	21.5	43.2
Charleston, W. Va.	36.6	37.5	44.4	55.3	64.8	72.0	74.9	73.8	68.2	57.3	45.3	37.1	55.6
Charlotte	42.7	44.2	50.0	60.3	69.0	77.1	79.2	78.7	72.9	62.5	50.4	42.7	60.8
Cheyenne	25.4	27.3	32.4	42.6	52.9	63.0	70.0	67.7	58.6	47.5	34.2	29.5	45.9
Chicago	26.0	27.7	36.3	49.0	60.0	70.5	75.6	74.2	66.1	55.1	39.9	29.1	50.8
Cincinnati	33.7	35.1	42.7	54.2	64.2	73.4	76.9	75.7	69.0	57.9	44.6	35.3	55.2
Cleveland	28.4	28.5	35.1	47.0	58.0	67.8	71.9	70.4	64.2	53.4	41.3	30.5	49.7
Columbia, S.C.	46.9	48.4	54.4	63.6	72.2	79.7	81.6	80.5	75.3	64.7	53.7	46.4	64.0
Columbus	29.9	31.1	38.9	50.8	61.5	70.8	74.8	73.2	65.9	54.2	41.2	31.5	52.0
Concord, N.H.	21.2	22.7	31.7	43.8	55.5	64.5	69.6	67.4	59.3	48.7	37.6	25.0	45.6
Dallas	45.9	49.5	56.1	65.0	72.9	81.3	84.9	85.0	77.9	67.8	54.9	48.1	65.8
Denver	28.5	31.5	36.4	46.4	56.2	66.5	72.9	71.5	63.0	51.4	37.7	31.6	49.5
Des Moines	19.9	23.4	33.8	48.7	60.6	71.0	76.3	74.1	65.4	54.2	37.1	25.3	49.2
Detroit	26.9	27.2	34.8	47.6	59.0	69.7	74.4	72.8	65.1	53.8	40.4	29.9	50.1
El Paso	42.9	49.1	54.9	63.4	71.9	81.0	81.9	80.4	74.5	64.4	51.2	44.1	63.3
Great Falls	22.1	23.8	30.7	43.6	53.0	59.9	69.4	66.8	57.4	47.5	34.3	27.3	44.7
Hartford	26.0	27.1	36.0	48.5	59.9	68.7	73.4	71.2	63.3	53.0	41.3	28.9	49.8
Honolulu	72.5	72.4	72.8	74.2	75.9	77.9	78.8	79.4	79.2	78.2	75.9	73.6	75.9
Houston	53.6	55.8	61.3	68.5	76.0	81.6	83.0	83.2	79.2	71.4	60.8	55.7	69.2
Indianapolis	29.1	31.1	38.9	50.8	61.4	71.1	75.2	73.7	66.5	55.4	40.9	31.1	52.1
Jackson, Miss.	47.9	50.5	56.5	64.9	73.1	79.8	82.3	82.0	76.5	67.0	55.5	49.4	65.5
Jacksonville	55.9	57.5	62.2	68.7	75.8	80.8	82.6	82.3	79.4	71.0	61.7	56.1	69.5
Juneau	25.1	26.8	30.4	38.0	45.6	52.3	55.3	54.1	48.9	41.6	34.3	28.4	40.1
Kansas City, Mo	31.7	35.8	43.3	55.7	65.6	75.9	81.5	79.8	71.3	60.2	44.6	35.8	56.8
Little Rock	40.6	44.4	51.8	62.4	70.5	78.9	81.9	81.3	74.3	63.1	49.5	41.9	61.7
Los Angeles	55.8	57.1	59.4	61.8	64.8	68.0	73.0	73.1	71.9	67.4	62.7	58.2	64.4
Louisville	35.0	35.8	43.3	54.8	64.4	73.4	77.6	76.2	69.5	57.9	44.7	36.3	55.7
Memphis	41.5	44.1	51.1	61.4	70.3	78.5	81.3	80.5	73.9	63.1	50.1	42.5	61.5
Miami	66.9	67.9	70.5	74.2	77.6	80.8	81.8	82.3	81.3	77.8	72.4	68.1	75.1
Milwaukee	20.6	22.4	31.0	43.6	53.4	63.3	68.7	67.8	60.3	50.0	35.8	24.6	45.1
Minneapolis	12.4	15.7	27.4	44.3	57.3	66.8	72.3	70.0	60.4	48.9	31.2	18.1	43.7
Mobile	53.0	55.2	60.3	67.6	75.6	81.5	82.6	82.1	77.9	69.9	58.9	54.1	68.2
Nashville	39.9	42.0	49.1	59.6	68.6	77.4	80.2	79.2	72.8	61.5	48.5	41.4	60.0
New Orleans	54.6	57.1	61.4	67.9	74.4	80.1	81.6	81.9	78.3	70.4	60.0	55.4	68.6
New York City	33.2	33.4	40.5	51.4	62.4	71.4	76.8	75.1	68.5	58.3	47.0	35.9	54.5
Norfolk	41.2	41.6	48.0	58.0	67.5	75.6	78.8	77.5	72.6	62.0	51.4	42.5	59.7
Oklahoma City	37.0	41.3	48.5	59.9	68.4	78.0	82.5	82.8	73.8	62.9	48.4	40.3	60.3
Omaha	22.3	26.5	36.9	51.7	63.0	73.1	78.5	76.2	66.9	55.7	38.9	28.2	51.5
Philadelphia	32.3	33.2	41.0	52.0	62.6	71.0	75.6	73.6	66.7	55.7	44.3	33.9	53.5
Phoenix	49.7	53.5	59.0	67.2	75.0	83.6	89.8	87.5	82.8	70.7	58.1	51.6	69.0
Pittsburgh	28.9	29.2	36.8	49.0	59.8	68.4	72.1	70.8	64.2	53.1	40.8	30.7	50.3
Portland, Me	21.8	22.8	31.4	42.5	53.0	62.1	68.1	66.8	58.7	48.6	38.1	25.8	45.0
Portland, Ore	38.4	42.0	46.1	51.8	57.4	62.0	67.2	66.6	62.2	54.2	45.1	41.3	52.9
Providence	29.2	29.7	37.0	47.2	57.5	66.2	72.1	70.5	63.2	53.2	43.0	32.0	50.1
Reno	30.4	35.6	41.5	48.0	53.9	60.1	67.7	65.5	58.8	49.2	38.3	31.9	48.4
Richmond	38.7	39.9	47.7	58.1	67.0	75.1	78.1	76.0	70.2	58.7	48.5	39.7	58.1
Sacramento	45.2	49.2	53.4	58.4	64.0	70.5	75.4	74.1	71.6	63.5	52.9	46.4	60.4
St. Louis	31.9	34.7	42.6	54.9	64.2	74.1	78.1	76.8	69.5	58.4	44.1	34.8	55.3
Salt Lake City	27.2	32.5	40.4	49.9	58.9	67.4	76.9	74.5	64.4	51.7	36.7	30.1	50.9
San Francisco	50.7	53.0	54.7	55.7	57.4	59.1	58.8	59.4	62.0	61.4	57.4	52.5	56.8
Seattle	38.3	40.8	43.8	49.2	55.5	59.8	64.9	64.1	59.9	52.4	43.9	40.8	51.1
Sioux Falls	15.2	19.1	30.1	45.9	58.3	68.1	74.3	71.8	61.8	50.3	32.6	21.1	45.7
Spokane	25.3	30.0	38.1	47.3	56.2	61.9	70.5	68.0	60.9	49.1	35.7	30.1	47.8
Washington, D.C.	36.9	37.8	44.8	55.7	65.8	74.2	78.2	76.5	69.7	59.0	47.7	38.1	57.0
Wichita	32.0	36.3	44.5	56.7	66.0	76.5	80.9	80.8	71.3	59.9	44.4	35.8	57.1
Wilmington	33.4	33.8	41.3	52.1	62.7	71.4	76.0	74.3	67.6	56.6	45.4	35.1	54.1

F. Internal Heat Generation

1. For the single-family residence and the town house, determine the total internal heat generation, QH_I, per residence from Figure 8 for each month based on the corresponding number of degree days for that month. For values beyond the range of the figure, use the end-point values. Example: A single-family residence during a 1000 heating degree month has an internal heat generation load of 2,780,000 Btu/month.

2. For the barracks, determine the total internal heat generation, QH_I, as follows.

   (a) Determine the heat generation correlation factor QH_O, from Figure 8-C for each month based on the corresponding number of degree days.

   (b) Determine the fractional occupancy level, FOL, by dividing the number of occupants by the maximum capacity of the barracks.

   (c) Determine the occupancy correction factor, OCF, from Table 2.

   (d) Calculate the internal heat generation from the following equation.

   $$QH_I = (QH_O)(FOL)(AREA)[1 + 1.334(OCF)]$$

   where,

   QH_O = Internal heat generation correlation factor from Figure 8-C

   FOL = Fractional occupancy level

   OCF = Occupancy correction factor from Table 2

   AREA = Floor area of barracks, sq ft

   Example: A 36,000 sq ft barracks during a 1000 heating degree day month has a fractional occupancy level of 0.80. From Figure 8-C, QH_O = 430. From Table 2, for FOL=0.80, OCF=1.18. Then,

   $$QH_I = (430)\ (0.80)(36{,}000)[1+1.334(1.18)]$$

   $$= 31{,}900{,}000 \text{ Btu/month}$$

Table 2 . OCCUPANCY CORRECTION FACTORS

Percent Occupancy	Correction Factor	Percent Occupancy	Correction Factor	Percent Occupancy	Correction Factor
150	0.78	75	1.23	25	2.04
140	0.80	70	1.28	20	2.20
130	0.83	65	1.34	15	2.53
120	0.87	60	1.39	10	2.86
110	0.93	55	1.46	8	3.13
100	1.00	50	1.52	6	3.57
95	1.04	45	1.60	4	4.30
90	1.08	40	1.67	2	5.93
85	1.13	35	1.78	Inactive	0.0
80	1.18	30	1.88		

SOURCE: Repairs and Utilities Utilization Targets and Evaluation, Department of the Army Technical Bulletin, TB ENG 259, 13 March 1961.

3. For an administration building, determine the total internal heat generation, QH_I, as follows.

(a) Determine the internal heat generation correlation factor, QH_O, from Figure 8-D for each month based on the corresponding number of heating degree days.

(b) Determine the fractional occupancy level, FOL, by dividing the number of occupants by the maximum capacity of the building.

(c) Calculate the internal heat generation from the following equation.

$$QH_I = (QH_O)(AREA)(FOL + 10.3)$$

where,

QH_O = Internal heat generation correlation factor from Figure 8-D

FOL = Fractional occupancy level

AREA = Floor area of administration building, sq ft

Example: A 12,600 sq ft administration building during a 1000 heating degree day month has a fractional occupancy level of 0.80. From Figure 8-D, QH_O=2600. Then,

$$QH_I = (2600)(12,600)\ [0.80 + 10.3)]$$

$$= 364,000,000 \text{ Btu/month}$$

4. For a commissary, determine the total internal heat generation, QH_I, as follows.

(a) Determine the internal heat generation correlation factor, QH_O, from Figure 8-E for each month based on the corresponding number of heating degree days.

(b) Determine the fractional occupancy level, FOL, by dividing the number of occupants in the commissary by the maximum number of customers and employees (building capacity).

(c) Calculate the internal heat generation from the following equation.

$$QH_I = (QH_O)(AREA)\ (FOL + 3.89)$$

where,

QH_o = Internal heat generation correlation factor from Figure 8-D

FOL = Fractional occupancy level

AREA = Floor area of administration building, sq ft

Example: A 25,000 sq ft commissary during a 1000 heating degree day month has a fractional occupancy level of 0.80. From Figure 8-D, QH_o = 4800. Then,

$$QH_I \ (4800)\ (25{,}000)\ (0.80 + 3.89)$$

$$= 563{,}000{,}000 \text{ Btu/month}$$

G. Interior Walls Heating Load

1. For the single-family residence, the town house, the barracks, and the administration building, the heating load due to interior walls, QH_{iw} = 0.

2. For the commissary, determine the heating load due to interior walls, QH_{iw}, as follows:

   (a) Determine the interior wall equivalent U value, EU_r, for the walls between the store and the refrigerated storage room, that have internal temperatures less than 55°F as per Building Heating Load, Section II-B.2 of this manual. For areas of glass sliders and sliding glass doors, multiply the glass area by 2.0, and use a U value of 0.75. For wall openings, multiply the opening area by 50, and use a U value of 0.50.

   (b) Determine the interior wall equivalent U value for the wall between the store and the frozen storage room, EU_f, as per Building Heating Load Section II-B.2 of this manual. For areas of glass sliders and sliding glass doors, multiply the glass area by 2.0, and use U value of 0.75. For wall openings, multiply the opening area by 50, and use a U value of 0.50.

   (c) Calculate the heating load due to interior walls from the following equation.

$$QH_{iw} = CH_F[(EA_r)(EU_r)(T_i - T_r) + (EA_f)(EU_f)(T_i - T_f)]$$

where,

CH_F = Correlation factor from Figure 7-E

EA_r = Equivalent wall area between the store and the refrigerated storage room, sq ft

EU_r = Equivalent U value of the wall between the store and the refrigerated storage room $Btu/hr\text{-}ft^2\text{-}°F$.

T_i = Store set-point temperature, °F

T_r = Refrigerated storage temperature, °F

EA_f = Equivalent wall area between the store and the frozen storage room

EU_f = Equivalent U value of the wall between the store and the frozen storage room, $Btu/hr\text{-}ft^2\text{-}°F$

T_f = Frozen storage temperature.

Example: A commissary has a 300 sq ft interior wall (U=0.25) with 30 sq ft of open area and 20 sq ft of slider windows between the store and the refrigerated storage room, and a 200 sq ft interior wall of U=0.25 between the store and the frozen storage room. The store is maintained at 72°F, the frozen storage at 0°F, and the refrigerated storage at 38°F during a 1000 heating degree day month. Then,

$$EA_r = 300-(30+20)+50(30)+2(20) = 1790$$

$$EU_r = \frac{250\ (0.25)+1500(0.5)+40(0.75)}{1790}$$

$$= 0.471$$

$$QH_{iw} = (675)[(1790)(0.471)(72-38)+(200)(0.25)(72-0)$$

$$= 21{,}800{,}000 \text{ Btu/month}$$

H. Heating Energy Use

1. Determine the total heating load, QH_{total}, from the following equation.

$$QH_{total} = QH_{env} + QH_{inf} - QH_{rad} + QH_{floor} + QH_{iw} - QH_{I}$$

where,

QH_{env} = Building envelope heating load

QH_{inf} = Infiltration heating load

QH_{rad} = Solar radiation heat gain

QH_{floor} = Heating load due to underground floors and walls

QH_{iw} = Heating load due to interior walls

QH_{I} = Internal heat generation

Example: A single-family residence has an envelope heating load of 19,600,000 Btu/month, an infiltration heating load of 7,000,000 Btu/month, a solar radiation heat gain of 1,340,000 Btu/month, an underground floor and wall heating load of 1,050,000 Btu/month, and an internal heat generation of 2,780,000 Btu/month, then,

$$\begin{aligned} QH_{total} &= (19{,}600{,}000)+(7{,}000{,}000)-(1{,}340{,}000) \\ &+ (1{,}050{,}000)-(2{,}780{,}000) \\ &= 23{,}500{,}000 \text{ Btu/month} \end{aligned}$$

2. For single-family and town house residences, determine the heating energy use, Q_{heat}, as follows.

(a) If the furnace/boiler efficiency, E_f, is known for a particular installation, use that value. If it is not known, use $E_f = 0.75$ for regularly serviced boilers/furnace, $E_f = 1.0$ for electric furnace, and $E_f = 0.65$ for others.

(b) If the distribution efficiency, E_{dist}, is known for a particular installation, use that value. If it is not known, use $E_{dist} = 0.90$.

(c) Calculate the heating energy use by the following equation.

$$Q_{heat} = \frac{QH_{total}}{(E_f)\ (E_{dist})}$$

where,

QH_{total} = Total heating load, Btu/month

E_f = Furnace/boiler efficiency, E_f = 1.0 if served by a central plant

E_{dist} = Distribution efficiency

Example: A gas-heated residence has a heating load of 23,500,000 Btu/month. The furnace and distribution efficiencies are not known. Then,

$$Q_{heat} = \frac{23,500,000}{(0.65)(0.90)}$$

$$= 40,200,000 \text{ Btu/month.}$$

3. For the barracks, administration, and commissary structures determine the heating energy use, Q_{heat}, as follows.

(a) Divide the monthly total heating load, QH_{total}, by the boiler monthly capacity (boiler rating, Btu/hr x720) to obtain the load ratio, LR. For buildings on a central plant, use LR>0.3 for the cold months and LR<0.30 for the mild months.

(b) From Figure 17, determine the boiler load factor, BLF, for the calculated LR. For buildings on a central plant, use BLF = 1.0.

(c) Determine the load correction factor, LCF, for the distribution system in the structure and the corresponding LR value from Table 3.

(d) Determine the boiler efficiency, BE, from known building information. If BE is not known, use BE = 0.80. For buildings on a central plant, use BE = 1.0.

Table 3. LOAD CORRECTION FACTORS AND AUXILIARY ELECTRIC CONSUMPTION FOR HEATING SYSTEMS

System Type	LCF		C Kw-hr/cfm month	
	$LR > 0.30$	$LR \le 0.30$	$LR > 0.30$	$LR \le 0.30$
Multizone Fan System	1.2	2.61	0.81	0.7
Multizone Fan System with Two-pipe Fan Coil System	1.0	1.1	0.46	0.3
Reheat Fan System	1.0	1.0	0.86	0.66
Variable Volume Fan System With Baseboard Radiation Controlled by Outside Temperature	1.0	1.3	0.42	0.26
Variable Volume Fan System with Baseboard Radiation Controlled by Inside Temperature	1.2	1.6	0.42	0.26

(e) Calculate the heating energy use from the following equation.

$$Q_{heat} = \frac{QH_{total}(LCF)}{(BE)\ (BLF)}$$

Example: An administration building has a total heating load of 290,000,000 Btu/month. The heating system is a variable volume system with baseboard radiation controlled by outside temperature, with a boiler capacity of 500,000,000 Btu/month and boiler efficiency of 80 percent. Then, $LR=290\times10^6 \div 500\times10^6 = 0.58$. From Figure 17, BLF = 0.95. From Table 2, LCF = 1.0. Then,

$$Q_{heat} = \frac{(290{,}000{,}000)(1.0)}{(0.80)(0.95)}$$

$$= 382{,}000{,}000 \text{ Btu/month}$$

4. For the barracks, administration, and commissary structures, determine the auxiliary electric consumption, E_a, as follows.

(a) Determine the supply fan flow rate, R, in cfm. *If R is unknown*, use R = 1 cfm/sq ft floor area.

(b) From Table 3, determine the electric consumption rate, C, for the distribution system in the building and the proper LR value.

(c) Determine the auxiliary electric consumption, E_a, from the following equation.

$$E_a = (C)(R)$$

where,

C = Electric consumption rate from Table 3, Kw-hr/cfm-month

R = Supply fan flow rate, cfm

Example: A 25,000 sq ft commissary with a multizone system of unknown cfm capacity has a load ratio of 0.70. Then R = (1) (25000) = 25,000. From Table 3, C = 0.7. Then,

$$E_a = (0.7)(25{,}000)$$

$$= 17{,}500 \text{ Kw-hr/month}$$

5. For building systems that are shut down at night, the heating energy usage is calculated from the following equation.

$$QH_{total} = [1-(0.0292)(x)]\ (QH_{env} + QH_{inf} - QH_{rad} + QH_{floor} + QH_{iw} - QH_I)$$

where,

X = hours per day that the system is shut down

QH = building envelope heating load, Btu/month

QH_{inf} = Infiltration heating load, Btu/month

QH_{rad} = Solar radiation heat gain, Btu/month

QH_{floor} = Heating load due to underground floors and walls, Btu/month

QH_{ew} = Internal heat generation, Btu/month.

6. For buildings systems that are shut down at night, the energy consumption due to fans and pumps is calculated from the following equation.

$$E_a = (E_a)_{24\ hr}\ (1-\frac{X}{24})$$

where,

$(E_a)_{24\ hr}$ = Auxiliary electric consumption as calculated in Section II-H.4

X = Hours per day that the system is shut down

III. COOLING

A. Definitions

1. Building envelope area - As defined in Section II-A.1.

2. Cooling Degree Day - A cooling unit based upon temperature difference and time, similar to the heating degree day. It is applied to the envelope, underground floor, and internal load calculations.

3. Discomfort index cooling degree day - A cooling unit similar to the heating degree day and cooling degree day that includes wet bulb temperature as well as dry bulb temperature, given in Table 4. It is used only in the calculation of infiltration cooling load.

4. Energy efficiency ratio - The ratio of cooling output of an air conditioning system (Btu/hour) to the energy input to that system (watts).

5. Equivalent U value - As defined in Section II-A.2.

B. Building Envelope Cooling Load

1. Using the number of monthly cooling degree days for a given month, determine QC_1 from Figure 9. For values beyond the range of the figure, use the end-point values.

2. Determine the building envelope equivalent U values as per Building Envelope Heating Load Section II-B.2 of this manual.

3. Determine the conduction correction factor CC_1 from Figure 10 for the corresponding number of monthly cooling degree days. For values beyond the range of the figure, extend the curve linearly.

4. Determine the temperature correction factor FC_1, from the Figure 11 for the corresponding number of monthly cooling degree days. For values beyond the range of the figure, use the end-point values.

5. The monthly building envelope cooling load can be determined from the following equation.

$$QC_{env} = (K)(QC_1)(CDD)(CC_1)(A_{total})[1-FC_1(T-72)]$$

where,

K = 2.246×10^{-4} for a single-family residence
= 5.296×10^{-4} for a town house
= 0.209×10^{-4} for a barracks
= 0.850×10^{-4} for an administration building
= 0.425×10^{-4} for a commissary

QC_1 = Building envelope cooling load from Figure 9

CDD = Monthly cooling degree days

CC_1 = Conduction correlation factor from Figure 10

A_{total} = Building envelope area, sq ft

FC_1 = Set-point temperature correlation factor from Figure 11

T = Indoor set-point temperature, °F.

Example: A single-family residence maintained at 74°F has an envelope area of 3090 square feet with an equivalent U value of 0.262. The month has 400 cooling degree days. From Figure 9-A, QC_1 = 22,500 Btu per degree day. From Figure 10-A, CC_1 = 0.98. From Figure 11-A, FC_1 = 0.085.

Then,

$$QC_{env} = 2.24 \times 10^{-4} (22{,}500)(400)(0.98)(3090)$$

$$[1-0.085(74-72)]$$

$$= 5{,}070{,}000 \text{ Btu/month}$$

C. Infiltration/Mechanical Ventilation Cooling Load

1. Calculate the infiltration and mechanical ventilation rate, $I+V_r$, by the method described in Section II-C.

2. Calculate the infiltration cooling load as follows.

   (a) Determine the monthly total number of discomfort index cooling degree days from Table 4 for the city which is closest to the Army facility being evaluated.

   (b) Using the total number of discomfort index cooling degree days, determine the net infiltration cooling load per cfm of infiltration, QC_2, from Figure 12.

For values beyond the range of the figure, extend the curve linearly.

(c) Determine the set-point correlation factor, FC_2, from Figure 13 for the corresponding number of monthly discomfort index cooling degree days. For values beyond the range of the figure, use the end-point values.

(d) Calculate the infiltration cooling load from the following equation:

$$QC_{inf} = (I+V_r)(QC_2)[1-FC_2(T-72)]$$

where,

I = Infiltration rate, cfm

V_r = Mechanical ventilation rate, cfm

QC_2 = Net infiltration cooling load from Figure 12

FC_2 = Temperature set-point correlation factor from Figure 13

T = Indoor set-point temperature, °F.

Example: A St. Louis single-family residence is cooled to 74°F during the month of July. The infiltration rate is 226 cfm. From Table 4 for St. Louis in July there are 434 discomfort index cooling degree days. From Figure 12-A, QC_2 = 23,000 Btu/cfm. From Figure 13-A, FC_2 = 0.03. Then,

$$QC_{inf} = (226)(23{,}000)[1-0.03(74-72)]$$

$$= 4{,}890{,}000 \text{ Btu/month}$$

3. If a building system operates for some time with no outside air intake (i.e., no mechanical ventilation), and the air handling system operates with 100 percent recycled air, then Q_{inf} is modified as follows.

$$QC_{inf} = (QC_{inf})_{24\ hr}\left(1-\frac{X}{24}\right)$$

where,

$(QH_{inf})_{24\ hr}$ = Infiltration cooling load as calculated in Section III-C.

X = Hours per day system operates without using outside air.

Table 4. MONTHLY AND ANNUAL DISCOMFORT INDEX COOLING DEGREE DAYS

Station and Region	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Eastern Seaboard													
Rochester, NY	0	0	0	0	58	167	225	217	82	0	0	0	749
Boston, MA	0	0	0	0	20	214	279	271	91	13	0	0	886
New York City, NY	0	0	0	0	48	270	326	349	135	36	0	0	1164
Washington, DC	0	0	0	33	109	315	388	372	175	52	11	0	1455
Raleigh, NC	0	0	15	57	204	345	442	419	218	88	24	20	1832
Hatteras, NC	0	0	11	71	185	428	504	481	353	233	57	57	2380
Charleston, SC	0	47	50	119	326	413	512	481	285	178	43	64	2519
Tallahassee, FL	0	78	76	120	364	403	481	496	338	233	59	85	2733
Jacksonville, FL	0	125	99	165	411	443	543	535	383	305	97	107	3213
Tampa, FL	32	166	157	218	450	473	519	527	420	341	154	178	3635
Miami, FL	124	261	256	323	481	488	548	558	495	457	233	146	4370
Southern Section													
Atlanta, GA	0	12	28	77	289	368	465	450	263	121	19	39	2131
Montgomery, AL	0	48	44	106	372	420	496	519	308	171	27	68	2579
Jackson, MS	0	50	50	107	372	413	512	481	300	302	60	47	2694
Shreveport, LA	22	54	57	137	395	450	566	550	360	198	49	47	2885
New Orleans, LA	26	103	118	200	349	450	543	527	420	310	121	119	3283
Dallas, TX	0	25	68	101	419	533	605	574	413	251	21	22	3032
Abilene, TX	0	16	46	114	310	465	504	481	330	172	12	0	2450
San Antonio, TX	25	70	90	185	403	503	535	481	405	271	50	48	3066
Houston, TX	39	99	113	158	419	413	550	550	428	295	105	85	3254
Laredo, TX	45	164	217	293	473	548	589	597	488	403	97	73	3987
Brownsville, TX	129	200	238	360	457	488	535	558	465	411	142	150	4133
North Central and Mid-west													
Sault Saint Marie, MI	0	0	0	0	0	49	64	119	12	0	0	0	244
Fargo, ND	0	0	0	0	22	248	209	211	27	0	0	0	717
Minneapolis, MN	0	0	0	0	59	279	240	266	52	27	0	0	923
North Platte, NB	0	0	0	0	79	285	318	264	91	0	0	0	1037
Chicago, IL	0	0	0	18	95	300	302	326	97	37	0	0	1175
Columbus, OH	0	0	0	21	109	276	341	318	110	35	0	0	1210

SOURCE: Thom, E.C., "A New Concept for Cooling Degree Days," Air Conditioning, Heating and Ventilating, June 1957.

Table 4.(cont.) MONTHLY AND ANNUAL DISCOMFORT INDEX COOLING DEGREE DAYS

Station and Region	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Kansas City, MO	0	0	0	41	232	390	473	457	198	114	0	0	1905
St. Louis, MO	0	0	12	41	200	370	434	434	202	87	13	0	1793
Amarillo, TX	0	0	0	0	154	354	364	318	203	77	0	0	1470
Oklahoma City, OK	0	0	25	61	104	405	481	457	300	136	0	0	1969
Ft. Smith, AZ	0	0	31	56	333	413	527	519	278	145	0	0	2302
Memphis, TN	0	13	18	82	326	413	527	504	248	126	28	24	2309
Nashville, TN	0	0	20	64	258	368	488	457	225	92	0	0	1972
Knoxville, TN	0	0	23	50	241	335	419	411	210	90	0	0	1779
Mountains and Southwest													
Billings, MT	0	0	0	0	56	178	240	168	48	0	0	0	690
Casper, WY	0	0	0	0	0	87	147	75	24	0	0	0	333
Reno, NV	0	0	0	0	15	36	132	62	21	0	0	0	266
Salt Lake City, UT	0	0	0	0	54	68	271	178	84	0	0	0	655
Denver, CO	0	0	0	0	21	188	194	145	54	0	0	0	602
Las Vegas, NV	0	0	0	31	163	338	457	380	323	68	0	0	1760
Winslow, AZ	0	0	0	0	34	180	237	209	135	0	0	0	845
Albuquerque, NM	0	0	0	0	54	270	287	247	173	34	0	0	1065
Yuma, AZ	0	0	56	123	147	480	615	581	570	244	27	0	2843
Phoenix, AZ	0	0	29	96	279	450	543	496	443	163	0	0	2499
Tucson, AZ	0	0	0	41	225	420	465	434	390	197	0	0	2172
El Paso, TX	0	0	0	21	279	383	388	364	330	87	0	0	1852
Pacific Coastal Area													
Seattle, WA	0	0	0	0	30	0	119	98	17	0	0	0	264
Red Bluff, CA	0	0	0	41	138	278	426	318	225	56	0	0	1492
Sacramento, CA	0	0	0	20	65	203	264	217	188	62	0	0	1039
San Francisco, CA	0	0	0	0	-11	31	43	48	75	10	0	0	218
Fresno, CA	0	0	0	54	102	248	372	295	270	96	0	0	1437
Bakersfield, CA	0	0	14	74	183	300	427	349	308	108	0	0	1763
Los Angeles, CA	0	0	0	11	46	203	202	235	218	109	42	0	1066

D. Solar Radiation Heat Gain

1. Determine the solar radiation coefficient, CR, for the latitude and month from Figure 14. CR_1 corresponds to cooling in the months of May, June, July, and August. CR_3 corresponds to cooling in the months of March, April, September, and October. For values beyond the range of the figure, use the end-point values.

2. Determine the incident radiation, IR, from Table 1 for the given month and location. Use the data from Table 1 for the city which is closest to the Army facility being evaluated.

3. Calculate the solar radiation cooling load, QC_{rad}, by the method described in Section II-D.3.

Example: A St. Louis single-family residence has 250 square feet of window area. For July, from Figure 14, CR = 0.15. From Table 1, IR - 574. Then,

$$QC_{rad} = 3.687(31)(574)(250)(0.15) = 2{,}450{,}000 \text{ Btu/month}$$

E. Underground Floors and Walls Cooling Load

1. Determine the cooling load due to underground floors and walls, QC_{floor}, as follows.

   (a) Determine the correlation factor, CC_F, for the corresponding number of monthly cooling degree days from Figure 15. For values beyond the range of the figure, extend the curve linearly.

   (b) Determine the floor U value, U_f from Reference 1, or use $U_f = 0.1$.

   (c) Determine the underground wall U value, U_w, from Reference 1, or use $U_w = 0.15$.

   (d) Determine the average monthly temperature from Table 1-B. For locations not listed, choose the next closest location. Use this value to determine the monthly ground temperature, T_g, from Figure 19.

   (e) Calculate the load due to underground floors and walls from the following equation.

$$QC_{floor} = (CC_f)[(A_f)(U_f)+(A_w)(U_w)](T-T_g)$$

where,

CC_F = Correction factor from Figure 15

A_f = Area of underground floors, sq ft

U_f = Floor U value from Reference 1, Btu/hr-ft^2-°F

A_w = Area of underground walls, sq ft

U_w = Underground wall U value from Reference 1, Btu/hr-ft^2-°F

T = Inside set-point temperature, °F

T_g = Ground temperature from Figure 19, °F.

Example: A 1100 square foot area single-family residence built on a slab has an indoor set-point temperature of 74°F. During a 400 cooling degree day month, the ground temperature is 65°F. From Figure 15-A, CC_F = 725. From Table 1, U_f=0.10 and U_w = 0.15. Then,

$$QC_{floor} = (725)[(1100)(0.1)+(0)](74-65)$$
$$= 79{,}800 \text{ Btu/month.}$$

F. Internal Heat Generation

1. For a single-family residence or a town house, determine the total internal heat generation, QC_I, from Figure 16 for each month based on corresponding number of cooling degree days. For values beyond the range of the figure, use the end-point values. Example: A single-family residence during a 400 cooling degree day month has an internal heat generation load of 3,500,000 Btu/month.

2. For a barracks, determine the total internal heat generation, QC_I, as follows.

(a) Determine the heat generation due to occupants, QC_O, from Figure 16-C for each month based on the corresponding number of cooling degree days.

(b) Determine the fractional occupancy level, FOL, by dividing the number of occupants by the capacity of the barracks.

(c) Determine the occupancy correction factor, OCF, from Table 2.

(d) Calculate the total internal heat generation, QC_I, from the following equation.

$$QC_I = (QC_O)(AREA)(FOL)[1.61 + 1.43\,(OCF)]$$

where:

QC_O = Internal heat generation correlation from Figure 16

AREA = Area of barracks, sq ft

FOL = Fractional occupancy level

OCF = Occupancy correction factor from Table 2.

Example: A 36,000 sq ft barracks is 50 percent occupied during a 300 cooling degree day month. From Figure 16-C, $QC_O = 425$. From Table 2, at FOL = 0.50, OCF = 1.52. Then,

$$QC_I = (425)(36{,}000)(0.5)[1.61+1.43(1.52)]$$

$$= 28{,}900{,}000 \text{ Btu/month}$$

3. For an administration building, determine the total internal heat generation, QC_I, as follows.

(a) Determine the heat generation due to occupants, QC_O, from Figure 16-C for each month based on the corresponding number of cooling degree days.

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(b) Determine the fractional occupancy level, FOL, by dividing the number of occupants by the capacity of the building.

(c) Calculate the total internal heat generation, QC_I from the following equation.

$$QC_I = (QC_O)(AREA)[(FOL)(1.613)+13.4]$$

where,

QC_O = Internal heat generation correlation factor from Figure 16

AREA = Area of administration building, sq ft

FOL = Fractional occupancy level

Example: A 12,600 administration building is 75 percent occupied during a 300 cooling degree day month. From Figure 16-D, QC_O = 320. Then,

$$QC_I = (320)(12,600)[(0.75)(1.613)+13.4]$$

$$= 59,100,000 \text{ Btu/month}.$$

4. For a commissary, determine the total internal heat generation, QC_I, as follows.

(a) Determine the heat generation due to occupants, QC_O, from Figure 16-E for each month based on the corresponding number of cooling degree days.

(b) Determine the fractional occupancy level, FOL, by dividing the number of occupants by the capacity of the commissary (customers plus employees).

(c) Calculate the total internal heat generation, QC_I, from the following equation.

$$QC_I = (QC_O)(AREA)[(FOL)(1.626)+5.06]$$

where,

QC_o = Internal heat generation correlation factor from Figure 16

AREA = Area of commissary, sq ft

FOL = Fractional occupancy level

Example: A 25,000 sq ft commissary has an 80 percent occupancy level during a 300 cooling degree day month. From Figure 16-E, QC_o = 1.05. Then,

$$QC_I = (1.05)(25{,}000)[(0.80)(1.626)+5.06]$$

$$= 167{,}000{,}000 \text{ Btu/month.}$$

G. Interior Walls Cooling Load

1. For the single-family residence, town house, barracks, and administration building, the cooling load due to interior walls, QC_{iw}, is zero.

2. For the commissary determine the cooling load for interior walls during the cooling season as follows.

   (a) Determine the interior wall equivalent U value for the wall between the store and the refrigerated storage room, U_r, as per Building Heating Load Section II-B.2 of this manual for storage room temperature of less than 50°F. For areas of glass sliders and sliding glass doors, multiply the glass area by 2.0, and use a U value of 0.75. For wall openings, multiply the opening area by 50, and use a U value of 0.50.

   (b) Determine the interior wall equivalent U value for the wall between the store and the frozen storage room, EU_f, as per Building Heating Load Section II-B.2 of this manual. For areas of glass sliders and sliding glass doors, multiply the glass area by 2.0, and use a U value of 0.75. For wall openings, multiply the opening area by 50, and use a U value of 0.50.

   (c) Calculate the cooling load due to interior walls from the following equation.

$$QC_{iw} = CC_F[(EA_r)(EU_r)(T_i-T_r)+(EA_f)(EU_f)(T_i-T_f)]$$

where,

CC_F = Correction factor from Figure 15-E

EA_r = Equivalent wall area between the store and the refrigerated storage room, sq ft

EU_r = Equivalent U value of the wall between the store and the refrigerated storage room, Btu/hr-ft^2-°F

T_i = Store set-point temperature, °F

T_r = Refrigerated storage temperature, °F

EA_f = Equivalent wall area between the store and the frozen storage room

EU_f = Equivalent U value of the wall between the store, and the frozen storage room, Btu/hr-ft^2-°F

T_f = Frozen storage temperature, °F

Example: A commissary has a 300 sq ft interior wall U=0.25 with 30 sq ft of open area and 20 sq ft of slider windows between the store and the refrigerated storage room, and a 200 sq ft interior wall (U=0.25) between the store and the frozen storage room. The store is maintained at 72°F, the frozen storage at 0°F, and the refrigerated storage at 38°F during a 300 cooling degree day month. Then CC_F = 600,

$$EA_r = 300-(30+20)+50(30)+2(20)$$
$$= 1790$$
$$EU_r = \frac{250(0.2+1500(0.5)+40(0.75)}{1790}$$

$$= 0.471$$

$$QC_{iw} = (600)[1790)(0.471)(72-38)+(200)(0.25)(72-0)]$$

$$= 19{,}400{,}000 \text{ Btu/month.}$$

H. Cooling Energy Use

1. Determine the total cooling load, QC_{total}, by the following equation.

$$QC_{total} = QC_{env} + QC_{inf} + QC_{rad} - QC_{floor} - QC_{iw} + QC_{I}$$

where,

QC_{env} = Building envelope cooling load

QC_{inf} = Infiltration cooling load

QC_{rad} = Solar radiation cooling load

QC_{floor} = Cooling load due to underground floors and walls

QC_{iw} = Cooling load due to interior walls

QC_{I} = Interior heat generation.

Example: A residence has an envelope cooling load of 7,140,000 Btu/month, an infiltration cooling load of 5,200,000 Btu/month, a solar radiation cooling load of 2,450,000 Btu/month, an underground floor and wall cooling load of 79,800 Btu/month, and an internal cooling load of 3,500,000 Btu/month. Then,

$$QC_{total} = (7,140,000)+(5,200,000)+(2,450,000)-(79,800)+(0)+(3,500,000)$$

$$= 18,200,000 \text{ Btu/month}$$

2. For the single-family and town house, determine the cooling energy use, Q_{cool}, as follows.

   (a) Utilize the energy efficiency rating (EER) for systems where it it known. If unknown, use EER=5.0 for window units, EER=6.0 for split systems (central electric), and EER=1.7 for gas absorption units.

   (b) If the distribution efficiency, E_{dist}, is known for a particular installation, use that value. If it is not known, use E_{dist}=0.90 for central system, and E_{dist}=1.0 for window units.

(c) Calculate the cooling energy use by the following equation.

$$Q_{cool} = \frac{QC_{total}}{(1000)(EER)(E_{dist})}$$

where,

Q_{cool} = Cooling energy use, Kw-hr/month for electric chillers, and 10^3 Btu/month for gas absorption chillers

QC_{total} = Total cooling load, Btu/month

EER = Energy efficiency rating, Btu/watt-hr

E_{dist} = Efficiency of distribution system

Example: A single-family residence is cooled by a split system and has a cooling load of 18,200,000 Btu/month. Then,

$$Q_{cool} = \frac{18,200,000}{(1000)(6.0)(0.9)}$$

(d) For residences on a district cooling system, the equation to calculate the cooling energy use reduces to the following.

$$Q_{cool} = \frac{QC_{total}}{E_{dist}}$$

where,

QC_{total} = Total cooling load, Btu/month

E_{dist} = Distribution efficiency.

3. For the barracks, administration, and commissary buildings not on district cooling systems, determine the cooling energy use as follows.

(a) Divide the monthly total cooling load, QCtotal, by the monthly chiller capacity, CC, (chiller capacity) (Btu/hrx720) to obtain the load ratio, LR.

(b) Determine the chiller load factor, CLF, from Figure 18 for the type of chiller utilized in the particular installation.

(c) Determine the load correction factor, LCF, from Table 5 for the proper system and chiller load factor.

(d) Determine the EER value for the air conditioning equipment. If it is not known, use EER = 12.0 for electric chillers and EER=2.2 for absorption chillers.

(e) Calculate the cooling energy use from the following equation.

$$Q_{cool} = \frac{(CC)(LCF)(CLF)}{(1000)(EER)}$$

where,

Q_{cool} = Cooling energy use, Kw-hr/month (for electric chillers) or 10^3 Btu/month (for absorption chillers)

CC = Chiller capacity, Btu/month

LCF = Load correction factor from Table 5

CLF = Chiller load factor

EER = Energy efficiency rating, Btu/watt-hr.

Example: An administration building has a total cooling load of 200,000,000 Btu/month. The cooling system is a variable volume system with baseboard radiation. The centrifugal chiller system has an EER of 10.5 and a capacity of 350,000,000 Btu/month. From Table 5, LCF = 1.1. Then,

$$Q_{cool} = \frac{(350,000,000)(1.1)(0.50)}{(1000)(10.5)}$$

$$= 18,000 \text{ Kw-hr/month}.$$

(f) For buildings on a district cooling system, use the following equation.

$$Q_{cool} = (QC_{total})(LCF)$$

where,

Q_{cool} = Cooling energy use, Btu/month

QC_{total} = Total cooling load, Btu/month

LCF = Load correction factor from Table 5 (using LR $<$ 0.30 for hot months and LR $>$ 0.30 for mild months.),

Table 5. LOAD CORRECTION FACTORS AND AUXILIARY ELECTRIC CONSUMPTION FOR COOLING SYSTEMS

System Type	LCF		RF		C Kw-hr/cfm month	
	LR > 0.30	LR ≤ 0.30	LR > 0.30	LR ≤ 0.30	LR > 0.30	LR ≤ 0.30
Multizone Fan System	2.0	2.8	--	--	1.1	0.86
Multizone Fan System with Two-Pipe Fan Coil System	1.2	2.5	--	--	0.69	0.37
Reheat Fan System	4.6	7.1	0.4	0.8	1.2	0.83
Variable Volume Fan System with Baseboard Radiation	1.1	1.9	--	--	0.62	0.31

4. For a reheat fan system in a barracks, administration building, and a commissary, determine the reheat load, Q_{rh} as follows.

   (a) Determine the reheat factor, RF, from Table 5 for the proper chiller load factor.

   (b) Calculate the reheat load, Q_{rh}, from the following equation.

   $$Q_{rh} = (QC_{total})(RF)(LCF)$$

   where,

   QC_{total} = Total cooling load, Btu/month

   RF = Reheat factor from Table 5, Btu/month

   LCF = Load Correction factor from Table 5.

   (c) Determine the reheating energy requirements, Q_{heat}, as per heating energy use, Section II-H.3.

5. For the barracks, administration, and commissary structures, the auxiliary electric consumption, E_a, is determined as follows.

   (a) Determine the supply fan flow rate, R, in cfm. If R is unknown, use R = 1 cfm/sq ft floor area.

   (b) From Table 5, determine the electric consumption rate for fans and pumps, C, for the distribution system in the building and the proper LR value for the month.

   (c) Determine the auxiliary electric consumption, E_a, from the following equation.

   $$E_a = (C)(R)$$

   Example: A 25,000 sq ft commissary with a multizone system of unknown cfm capacity has a load ratio, LR, equal to 0.70. Then, R = (1)(25000) = 25,000. From Table, 5, C = 0.86. Then,

   $$E_a = (0.86)(25{,}000) = 21{,}500 \text{ Kw-hr/month}$$

6. For building systems that are shut down at night, the cooling energy usage is calculated from the following equation.

$$QC_{total} = [1-0.0283(x)](QC_{env} + QC_{inf} + QC_{rad} - QC_{floor} - QC_{iw} + QC_{I})$$

where,

X	=	Number of hours per day system is shut down
QC_{env}	=	Building envelope cooling load
QC_{inf}	=	Infiltration cooling load from Section III-1.1.
QC_{rad}	=	Solar radiation cooling load
QC_{floor}	=	Cooling load due to underground floors
QC_{iw}	=	Cooling load due to interior walls
QC_{I}	=	Interior heat generation.

7. For building systems that are shut down at night, determine the energy consumption due to fans and pumps as follows.

$$E_a = (E_a)_{24\ hr}\ (1-\frac{X}{24})$$

where,

$(E_a)_{24\ hr}$	=	Auxiliary electric consumption as calculated in Section III-H.4.
X	=	Hours per day that the system is shut down.

IV. LIGHTING

Daily and monthly energy use calculation procedures are presented here. Annual or semi-annual energy use can be determined simply by multiplying daily usage by the appropriate number of days. Single-family and town house residences have been treated alike for these energy use calculations and are identified as family housing.

A. Family Housing

The electricity consumption due to lighting in family housing units is dependent upon the living area of the residence and the number of occupants in the building. Residences occupied by the average family of four will use energy for lighting at a rate of about 1.19 Kw-hr/square foot/year. A similar residence occupied by only one or two people will use about two-thirds as much lighting energy. Daily lighting energy use values are given in the following table (in Kw-hr/square foot/day).

Number of Occupants	Lighting Energy Usage
One or two	2.17×10^{-3}
Three or more	3.25×10^{-3}

Monthly energy use can be calculated by multiplying daily values by the number of days in any month.

B. Barracks

The lighting energy use in a barracks can be calculated as follows.

(1) Multiply the floor area (in square feet) of all occupied sleeping or bunking areas by 0.0040 Kw-hr/square foot/day to attain lighting energy on a daily basis.

(2) Multiply the floor area (in square feet) of all other areas of the barracks (excluding unoccupied bunking areas) by 0.0104 Kw-hr/square foot/day. Add this value to the result from (1).

(3) If the bunking area in the barracks is not known, use 0.007 Kw-hr/square foot/day for the entire floor area of the barracks.

(4) Multiply the result (from (1) and (2), or from (3)) by the fractional value of occupancy of the building; i.e., multiply by 0.60 if the barrack is only sixty percent occupied. Then multiply by the occupancy correction factor from Table 2 for the appropriate occupancy level.

$$\frac{\text{Kw-hr}}{\text{sq ft-day}} \times \begin{array}{c}\text{Fractional}\\ \text{Occupancy}\end{array} \times \begin{array}{c}\text{Occupancy}\\ \text{Correction}\\ \text{Factor}\end{array} = \begin{array}{c}\text{Indoor}\\ \text{Lighting}\\ \text{Energy Use}\\ \text{(Kw-hr/day)}\end{array}$$

In addition, outdoor lighting energy use must be accounted for where it exists. The wattage rating of outdoor lights and the average number of hours of operation per day can be used to determine hourly electric energy use by outdoor lights.

$$\begin{array}{c}\text{Outdoor}\\ \text{Lighting Energy}\\ \text{Usage (Kw-hr/day)}\end{array} = \frac{\begin{array}{c}\text{Wattage Rating}\\ \text{of Lights (watts)}\end{array} \times \begin{array}{c}\text{Hours of}\\ \text{Operation}\\ \text{per day (hours)}\end{array}}{1000}$$

Monthly energy use can be determined by multiplying total daily energy use value by the number of days in month.

C. Administration/Office Building

The lighting energy use in an administration/office building can be determined in the following manner:

(1) Accumulate the total wattage of all installed lighting equipment in the building. If installed lighting equipment rating is not known, assume 2.5 watts/square foot, and multiply by the total floor area of the building.

(2) Determine the number of hours that a building is occupied per week. Account for normal weekday working hours (8 hours/day), and include half-days or full days normally worked on weekends. Consider second and third shifts, if any. Where three shifts exist, use 24 hours per day.

(3) The number of normal working hours must be increased to account for time during lunch breaks, after-hours maintenance, and some level of lighting which is on continuously. Where only one shift exists, a multiplier of 1.5 is used; for two shifts, use 1.2; for three shifts, use 1.0.

(4) Calculate the following to obtain lighting energy use:

$$\frac{\text{Total Wattage of Lights in Watts} \times \text{No. of Working Hours per Week} \times \text{Multiplier}}{7\ \frac{\text{days}}{\text{week}} \times 1000\ \text{watts/kilowatt}} = \text{Daily Lighting Energy (Kw-hr/day)}$$

Outdoor lighting energy use can be determined by the procedure defined for the barracks.

Monthly energy use can be calculated by multiplying the daily value by the number of days in a month.

D. Commissary

To determine the lighting energy use in a commissary:

(1) Accumulate the total wattage of all installed lighting equipment (or use 2 watts per square foot of floor space and multiply by total floor area).

(2) Multiply the wattage by 18 hours per day (average amount of time the lights are on) and divide by 1000 watts/kilowatt to obtain daily electricity consumption.

That is,

$$\frac{\text{Lighting Wattage} \times 18\ \frac{\text{hr}}{\text{day}}}{1000\ \text{watts/kilowatt}} = \text{Daily Lighting Energy (Kw-hr/day)}$$

or,

$$\frac{\frac{2\ \text{watts}}{\text{sq ft}} \times \text{Floor Area, sq ft} \times 18\ \frac{\text{hr}}{\text{day}}}{1000\ \text{watts/kilowatt}} = \text{Daily Lighting Energy (Kw-hr/day)}$$

Outdoor lighting energy use can be determined by the procedure defined for the barracks.

Monthly energy use can be calculated by multiplying the daily value by the number of days in a month.

V. COOKING

Daily and monthly energy use calculation procedures are presented here. Annual or semi-annual energy use can be determined simply by multiplying daily usage by the appropriate number of days. Single-family and town house residences have been treated alike for these energy use calculations and are identified as family housing.

A. Family Housing

Where an electric range and oven is utilized, the energy use for a family housing unit is 3.3 Kw-hr/day. In the case of a natural gas or propane range, the cooking energy is 2.9×10^4 Btu/day. If the gas range has no pilots (that is, uses electric ignition or other methods), the range and oven energy use is reduced to 1.9×10^4 Btu/day of gas. Monthly consumption can be calculated by multiplying daily energy use by the number of days in a month.

B. Barracks

Barracks without mess halls have no cooking energy use. The cooking energy use in a barracks with mess hall can be determined in one of two ways.

(1) If the number of individual meals served per day is known, the daily cooking energy use for the barrack can be determined by multiplying the total number of person-meals served per day by 2300 Btu/person-meal.

(2) Or, multiply the total number of residents in the barrack by 5000 Btu/day/occupant.

Monthly energy use can be determined by multiplying the daily usage by the number of days in a month.

C. Administration/Office Building

There is no cooking energy use in administration/office buildings.

D. Commissary

There is no cooking energy use in commissaries.

VI. HOT WATER HEATING

Daily and monthly energy use calculation procedures are presented here. Annual and semi-annual energy use can be determined simply by multiplying daily usage by the appropriate number of days. Single-family and town house residences have been treated alike for these energy use calculations and are identified as family housing.

A. Family Housing

The hot water heating energy use per housing unit for the different types of water heaters is as follows:

Electric	16.8 Kw-hr/day
Gas w/pilot	75,000 Btu/day
Gas w/o pilot	64,000 Btu/day
Oil	95,000 Btu/day

Propane and LP gas fueled water heaters will be considered in the appropriate category with natural-gas-fueled heaters. If the water heater is not a separate unit, but is part of the space heating furnace, use 95,000 Btu/day for water heating. If hot water is heated by steam delivered to the housing unit from a central steam generating facility, steam requirements will be 66 pounds of steam per day. Monthly energy use can be calculated by multiplying daily usage by the number of days in a month.

B. Barracks

For barracks which have hot water generated within the building from gas, propane, or LP gas water heaters, the energy use for water heating is:

17,800 Btu/day/occupant for barracks with mess halls

14,400 Btu/day/occupant for barracks without mess halls

Oil-fired water heaters use about 27 percent more fuel than the gas units, or:

22,500 Btu/day/occupant for barracks with mess halls

18,200 Btu/day/occupant for barracks without mess halls

For barracks which have central steam supplied to heat water, the steam requirements are:

16 lb of steam/day/occupant for barracks with mess halls

13 lb of steam/day/occupant for barracks without mess halls

Where hot water is heated electrically inside the barrack, the energy use is:

4.1 Kw-hr/day/occupant in barracks with mess hall

3.3 Kw-hr/day/occupant in barracks without mess hall

Energy use per day for hot water heating in a barrack can be determined by multiplying the appropriate value for the type of barrack and hot water heating system listed above by the total number of residents in the barrack. Monthly energy use can be calculated by multiplying the daily value by the number of days in a month.

C. Administration/Office Building

Hot water heating energy use in administration/office building is:

1000 Btu/day/employee for natural gas, LP gas, or propane water heaters

1270 Btu/day/employee for oil-fired water heaters

1.0 lb/day/employee for steam converters

0.23 Kw-hr/day/employee for electric heaters

When determining monthly or annual estimates from these figures, the total number of calendar days in a month or year is used.

D. Commissary

Hot water heating energy in commissaries can be determined using the following daily use values:

2500 Btu/day/employee for natural gas, LP gas, or propane water heaters

3170 Btu/day/employee for oil-fired water heaters

2.2 lb/day/employee for steam convertors

0.6 Kw-hr/day/employee for electric water heaters

When determining monthly or annual estimates from these figures, the total number of calendar days in a month or year is used.

VII. LAUNDRY

Daily and monthly energy use calculation procedures are presented here. Annual or semi-annual energy use can be determined simply by multiplying daily usage by the appropriate number of days. Single-family and town house residences have been treated alike for these energy use calculations and are identified as family housing.

A. Family Housing

The daily average laundry energy use in family housing units with the following laundry facilities is as follows:

Automatic Washing Machine	0.3 Kw-hr/day/family
Non-automatic Washing Machine	0.2 Kw-hr/day/family
Electric Dryer	2.7 Kw-hr/day/family
Gas Dryer with Pilot	24,700 Btu/day/family
Gas Dryer w/o Pilot	15,100 Btu/day/family

Monthly energy usage can be determined by multiplying these values by the number of days in any month.

B. Barracks - Laundromats

Energy use in laundromats and in self-service laundry facilities as provided in barracks can be determined as follows:

Automatic Washer	0.3 Kw-hr/day/family, or 0.1 Kw-hr/day/barracks resident
Gas Dryer w/Pilot	24,700 Btu/day/family, or 8,200 Btu/day/barracks resident

Some estimation must be made for each installation as to how many enlisted men and women living in barracks use the laundromat as opposed to a commercial laundry. Also, some estimate must be made for the number of families which normally use on-base laundromats.

C. Laundries

Only energy use in on-base laundries for which the military supplies fuels is of concern here. Daily or monthly energy use in such facilities can be determined using the number of articles of clothing laundered per day or month and the energy use multipliers (in million Btu/1000 articles of clothing laundered) for each month as follows:

	Million Btu/ 1000 Articles
January	13.2
February	14.4
March	11.2
April	8.6
May	9.0
June	7.5
July	8.0
August	8.0
September	7.8
October	10.3
November	12.3
December	14.4

These values represent equivalent energy of all fuels consumed.

VIII. COLD STORAGE

The energy use calculations in this section are applicable to cold storage units which are of the prefabricated and add-on type facility, or of the cold storage room type. These calculations can be utilized for refrigerator or freezer units. Two procedures are presented for estimating energy use by cold storage facilities. The first is a simplified procedure, to be used as a rough estimater, and is based on system capacity only. The second procedure encompasses factors such as wall U values infiltration rates and average weather data.

A. Simplified Method

(1) Determine the capacity, CAP, of the refrigeration system which cools the cold storage space, in Btu/hr. (One ton of refrigeration capacity equals 12,000 Btu/hr. One horsepower capacity equals 5100 Btu/hr). If capacity is unknown, assume 4 Btu/hr/cu ft of cold storage space.

(2) For each month studied, determine if the average monthly temperature is: (a) greater than 80°F, (b) less than 80°F but greater than 50°F, or (c) less than 50°F. If the average monthly temperature is greater than 80°F, the load ratio for the month, LR_m, is 0.8. If the average monthly temperature is less than 50°F, LR_m is 0.2. Otherwise, $LR_m = 0.5$.

(3) Determine the monthly energy use of the system as follows:

$$\text{Monthly Energy Use (Kw-hr/month)} = (CAP)(LR_m)(DM)(7.03\times10^{-3})$$

where,

CAP = Capacity of refrigeration systems, in Btu/hr.

LR_m = Load ratio for the month

DM = Number of days in the month

B. Load Component Method

(1) Calculate the total area of walls, roofs, and floors exposed to outside air temperatures (A_w). Do not include floors which are on the ground or on concrete slab. Calculate separately the area of ground/concrete floors (A_f). Also, determine the area of walls which is exposed to other conditioned areas with set points higher than 45°F (A_I).

(2) Determine the U value (thermal conductance) of each of the above wall areas, A_w, A_f, A_I. If these are unknown, assume 0.03 (U_w, U_f, U_I).

(3) Determine the number of hours of heat gain through walls exposed to outside air (H_o). This number will be different for each month of the year. In Reference 3 (TM 5-785, "Engineering Weather Data," Departments of the Air Force, the Army, and the Navy, 15 June 1967), Section C, find the location listed which is closest to the base being evaluated. This section provides distributions of typical observed temperatures in five degree ranges for each month. Table 6 shows an example from TM 5-785 of such a distribution. To determine the number of hours for any month during which the refrigerator unit experiences heat gain through walls exposed to outside air (H_o), add up the Total Observations column for the temperature ranges which represent outside temperatures higher than the set-point temperature of the cold storage space.

Example: For November, for a space cooled to 35°F, the sum of observations for 35/39 range and higher is, from Table 6:

$$H_o = 1 + 6 + 18 + 44 + 87 + 109 + 117 + 126 + 106$$
$$= 614$$

Table 6. EXAMPLE OF OBSERVED TEMPERATURE DISTRIBUTIONS FROM TM 5-785

Temperature Range (°F)	NOVEMBER Obsn/Hour Gp 02 to 09	NOVEMBER Obsn/Hour Gp 10 to 17	NOVEMBER Obsn/Hour Gp 18 to 01	NOVEMBER Total Obsn	NOVEMBER Mean Coincident Wet Bulb (°F)	DECEMBER Obsn/Hour Gp 02 to 09	DECEMBER Obsn/Hour Gp 10 to 17	DECEMBER Obsn/Hour Gp 18 to 01	DECEMBER Total Obsn	DECEMBER Mean Coincident Wet Bulb (°F)	JANUARY Obsn/Hour Gp 02 to 09	JANUARY Obsn/Hour Gp 10 to 17	JANUARY Obsn/Hour Gp 18 to 01	JANUARY Total Obsn	JANUARY Mean Coincident Wet Bulb (°F)
100/104															
95/99															
90/94															
85/89															
80/84		0		0	67										
75/79		1		1	67										
70/74	0	6		6	68				-						
65/69	3	12	3	18	60		2	0	2	59					
60/64	7	27	10	44	56	1	2	1	4	56	1	1	1	3	59
55/59	20	41	26	87	52	5	9	4	18	53	1	3	2	6	54
50/54	27	48	34	109	47	7	19	6	32	48	4	8	3	15	48
45/49	34	43	40	117	42	11	24	18	53	43	6	19	7	32	43
40/44	45	33	48	126	38	24	39	28	91	39	13	37	21	71	38
35/39	44	19	43	106	34	35	51	43	129	34	33	59	43	135	34
30/34	43	7	27	77	30	54	44	55	153	29	50	51	60	161	29
25/29	11	2	7	20	25	36	31	42	109	24	47	31	44	122	24
20/24	4	1	2	7	20	33	19	27	79	20	35	22	32	89	20
15/19	2		0	2	15	27	7	19	53	15	28	12	20	60	15
10/14						11	1	4	16	11	19	4	11	34	11
5/9						3	0	1	4	7	9	1	4	14	6
0/4						1		0	1	1	2		0	2	2
−5/−1															

Temperature Range (°F)	FEBRUARY Obsn/Hour Gp 02 to 09	FEBRUARY Obsn/Hour Gp 10 to 17	FEBRUARY Obsn/Hour Gp 18 to 01	FEBRUARY Total Obsn	FEBRUARY Mean Coincident Wet Bulb (°F)	MARCH Obsn/Hour Gp 02 to 09	MARCH Obsn/Hour Gp 10 to 17	MARCH Obsn/Hour Gp 18 to 01	MARCH Total Obsn	MARCH Mean Coincident Wet Bulb (°F)	APRIL Obsn/Hour Gp 02 to 09	APRIL Obsn/Hour Gp 10 to 17	APRIL Obsn/Hour Gp 18 to 01	APRIL Total Obsn	APRIL Mean Coincident Wet Bulb (°F)
100/104															
95/99															
90/94												0		0	67
85/89												3	0	3	67
80/84												9	1	10	65
75/79							2		2	58	0	12	2	14	62
70/74							5	0	5	57	2	14	6	22	60
65/69		1	0	1	57	0	6	2	8	55	5	21	11	37	56
60/64	0	4	0	4	56	2	9	4	15	52	14	31	17	62	53
55/59	2	5	4	11	53	4	16	7	27	49	23	43	26	92	50
50/54	3	12	4	19	47	5	28	12	45	44	34	42	38	114	66
45/49	4	23	9	36	42	12	45	23	80	40	41	35	52	128	42
40/44	18	36	25	79	38	39	52	53	144	37	55	24	53	132	38
35/39	43	50	44	137	34	67	47	70	184	34	43	5	27	75	34
30/34	42	44	62	148	29	61	24	47	132	29	20	1	6	27	30
25/29	49	23	38	110	24	34	11	19	64	24	3		1	4	24
20/24	26	15	18	59	19	14	3	9	26	20	0			0	20
15/19	19	7	13	39	15	8	0	2	10	15	0			0	17
10/14	11	3	6	20	10	2			2	11					
5/9	5	1	1	7	6										
0/4	1	0	0	1	1										
−5/−1	1			1	−4										

SOURCE: TM 5-785, Engineering Weather Data, Departments of the Air Force, the Army, and the Navy, 15 June 1967 (Reference 3).

(4) Determine the weighted average outside temperature for each month during the hours of heat gain through walls exposed to outside air (T_O). This weighted average temperature is computed by multiplying the average temperature for each temperature range by the total number of observed readings which exceed the set-point temperature of the cold space.

Example: For November and a 35°F set-point from Table 6.

Temperature Range °F	Average Temperature For Range	Total Observations	(2) x (3)
75/79	77	1	77
70/74	72	6	432
65/69	67	18	1,206
60/64	62	44	2,728
55/59	57	87	4,959
50/54	52	109	5,668
45/49	47	117	5,499
40/44	42	126	5,292
35/39	37	106	3,922
		614	29,783

Weighted average temperature, $T_O = \frac{29,763}{614} = 49$

(5) Determine the total number of hours in the month by multiplying the number of days in the month by 24 (H_m).

(6) Determine the average ground temperature for the month from available base data, as in Chapter II, Heating (T_G).

(7) Determine the rate of infiltration through doors opening into the building (CF_I). For each door which opens into a space conditioned to 55°F or above, assume 2000 cubic feet of infiltrated air per day for a door which has infiltration barriers in place when the door is open. Assume 20,000 cubic feet per day for doors with no infiltration barriers.

(8) The rate of infiltration through doors opening to the outside (CF_O) is 200 cubic feet per day for a door with infiltration barriers in place and 2000 cubic feet for a door without such barriers.

(9) The latent heat component of infiltration load (L) is determined from the following table depending on the set-point temperature for the cold storage space. Values should be interpolated for set-point temperatures between those shown in the table.

Set-Point Temperature, °F	L, Btu/cubic foot of air
-10	1.02
0	1.00
10	0.97
20	0.92
30	0.85
40	0.76

(10) TSP_1 is the set-point temperature in the cold storage space. TSP_2 is the set-point temperature in adjacent interior space(s). DM is the number of days in a month.

(11) Determine the energy efficiency rating (EER) of the refrigeration equipment. If EER is unknown, assume a value of 6.5.

(12) Determine monthly energy use of the cold storage unit as follows:

$$\text{Monthly Energy Use} = \frac{SL_W + SL_f + SL_I + IL_I + IL_o}{(EER)(1000)}$$

where,

$$SL_w = (A_w)\ (U_w)\ (H_o)\ \ (T_o - TSP_1 + 2)$$

$$SL_f = (A_f)\ (U_f)\ (H_m)\ \ (T_G - TSP_1)$$

$$SL_I = (A_I)\ (U_I)\ (H_m)\ \ (TSP_2 - TSP_1)$$

$$IL_I = (CF_I)\ (0.018)\ \ (TSP_2 - TSP_I) + L]\ \ \ (DM)$$

$$IL_o = (CF_o)\ (0.018)\ \ (T_o - TSP_1) + L]\ \ \ (DM)$$

For an example, consider a refrigerated box (set-point temperature, TSP_1, equals 35°F) with three walls and a roof exposed to outside air; total area of these surfaces equals 1010 square feet (A_w). Floor area on concrete slab equals 420 square feet (A_f). One wall is adjacent to a building which is conditioned at 65°F (TSP_2). The area of this wall is 110 square feet (A_I). The U value of all surfaces is assumed to be 0.03 (U_W, U_f and U_I). H_O, the number of hours for a month during which the outside temperature exceeds 35°F, is taken from the example under (3) above, i.e., 614 hours. T_O is also taken from the example under (4) above, an average temperature of 49°F. [H_O and T_O would be different for each month and each location, based on the data from Reference 3. This example is for the month of November, at the location (unspecified) for which data appears in Table 6]. H_m is 720 hours for November. Assume an average ground temperature of 55°F (TG). The box in this example has one door to an interior space at 65°F set-point and one door to the outside. Both have infiltration barriers in place when the doors are open (CF_I and CF_O are 2000 and 200 cu ft/day, *respectively*). DM is 30 days for the month of November. EER is 6.5. Therefore,

$$SL_W = (1010)\ (0.03)\ (614)\ \ (49 - 35 + 2) = 2.98\text{x}10^5$$

$$SL_f = (420)\ (0.03)\ (720)\ \ (55 - 35) = 1.81\text{x}10^5$$

$$SL_I = (110)\ (0.03)\ (720)\ \ (65 - 35) = 7.13\text{x}10^4$$

$$IL_I = (2000)[(0.018)\ \ (65 - 35) + 0.805](\text{x}30 = 8.07\text{x}10^4$$

$$IL_O = (200)[(0.018)\ (49 - 35) + 0.805](30) = 6.34\text{x}10^4$$

$$\text{Monthly Energy Use} = \frac{2.98\text{x}10^5 + 1.81\text{x}10^5 + 7.13\text{x}10^4 + 8.07\text{x}10^4 + 6.34\text{x}10^4}{(6.5)\ (1000)}$$

$$= \frac{6.94 \text{ x } 10^5}{6.5 \text{ x } 10^3}$$

$$= 107 \text{ Kw-hr}$$

IX. ELECTRICAL EQUIPMENT AND APPLIANCES

The electricity use calculations in this chapter are for equipment and appliances not included in other chapters (II, III, IV, VI, VII, VIII, and IX). Examples of appliances not included in this chapter's calculations are:

- Clothes washers and dryers (see Laundry)
- Electric lights (see Lighting)
- Ranges and ovens (see Cooking)
- Water heaters (see Hot Water Heating)

Daily and monthly energy use calculation procedures are presented here. Annual and semi-annual energy use can be determined simply by multiplying daily usage by the appropriate number of days. Single-family and town house residences have been treated alike for these energy use calculations and are identified as family housing.

A. Family Housing

The electricity usage for basic appliances in family housing units is 8.2 Kw-hr per day per dwelling. This basic load includes a refrigerator-freezer and numerous small appliances. For housing units with additional major electric appliances, add to this basic load the following values for each appliance.

Color TV	1.4 Kw-hr/day
Black and White TV	0.8 Kw-hr/day
Dishwasher	1.0 Kw-hr/day
Food Freezer	4.1 Kw-hr/day
Humidifier	0.4 Kw-hr/day
Dehumidifier	1.0 Kw-hr/day
Furnace Fan (for homes w/hot air distribution systems only)	1.1 Kw-hr/day

Monthly electricity usage can be calculated by multiplying the total daily usage by the number of days in a month.

B. Barrack, Commissary, and Administrative/Office Building

The daily electrical energy use due to equipment and appliances in these buildings is as shown in the following table.

Building Type	Electric Energy Usage	Units
Barrack (100% occupancy)	0.30	Kw-hr/day/resident
Commissary	0.06	Kw-hr/day/square foot of floor area
Administration/Office Building	2.45	Kw-hr/day/employee

For the barrack, the electric energy use per resident changes with occupancy level. The electric energy use value given for the barracks must be multiplied by the occupancy correction factor from Table 2 for the appropriate fractional occupancy level. Therefore, electrical appliance and equipment energy use per day for a barrack is equal to:

$$E_{EA} = (0.30)(OCF)\ (\text{Number of residents}).$$

Monthly electricity usage can be determined by multiplying these daily values by the number of days in a month.

X. ADDITIONAL ENERGY USERS

All energy using equipment and appliances which have not been considered in any of the preceding chapters must be accounted for. The energy consumption of such equipment can be estimated by determining the fuel consumption rate (or power rating in kilowatts for electric equipment) for each piece of equipment and multiplying this value by the estimate of the number of hours of operation of that equipment. That is:

$$\begin{pmatrix}\text{Fuel Consumption Rate,}\\ \text{gal/hr, cu ft/hr,}\\ \text{kilowatts, etc.}\end{pmatrix} \times \begin{pmatrix}\text{Hours of}\\ \text{Operation}\end{pmatrix} = \begin{pmatrix}\text{Fuel Consumed,}\\ \text{gal, cu ft,}\\ \text{Kw-hr, etc.}\end{pmatrix}$$

Note that all equipment does not always operate at the name plate rating. Therefore, base utilities and engineering personnel should be consulted to determine accurate estimates of the fuel consumption rate of equipment if it is anticipated to be a large energy consumer.

One example of previously unaccounted for energy users is emergency power generators. Another is outdoor gas lights. Typical gas light consumption is two cubic feet per hour or about 2000 Btu per hour of continuous operation.

Estimates for other energy users can best be made by base personnel.

XI. PIPELINE DISTRIBUTION LOSSES

This chapter is used to determine the efficiency of distributing energy in the form of steam, hot water or chilled water in underground pipelines. Such distribution efficiency is associated with central generating plants which produce steam or hot or chilled water for utilization in other buildings for purposes such as space heating and cooling and hot water heating. This chapter is not concerned with distribution within a building.

All pipelines are assumed to be buried over most of their length at some depth below the frost line.

A. Hot Water Pipelines

Heat losses due to distribution of hot water in underground pipelines are defined in Table 7 for various levels of insulation and numerous pipe sizes. The pipe size referred to in Table 7 is the nominal size of the pipe actually carrying hot water. (It is not the measure of the outside diameter of the exterior casing, or conduit). The configuration of the pipe, air gap, and insulation referred to in the table is as follows: the water-carrying pipe is surrounded by insulation, which is surrounded by an air space inside another pipe or casing. The daily heat loss rate in any section of pipeline can be determined by selecting the daily heat loss value (in Btu/day-foot-°F), from the table for the appropriate pipe size and insulation level and multiplying by the length of the distribution line (in feet) and the average ΔT (the difference between the temperature of the hot water and the average temperature of the ground for any month). The total heat loss for the distribution system can be determined by summing over all sections of pipe the product of the length of the section, the proper daily heat loss value from Table 7, and the number of days each month that hot water is transferred through that section of line.

Then the total heat loss for the system is,

$$HL_m = (T_{HW} - T_G) \quad x \quad \sum_i (DHLV_i)(L_i)(DM_i)$$

where,

i designates each unique pipe section

Table 7. DAILY HEAT LOSSES FOR UNDERGROUND HOT-WATER PIPE AND PIPE CONDUITS PER DEGREE TEMPERATURE DIFFERENCE FROM HOT WATER TO GROUND (BTU/DAY-FOOT-°F)

Nominal Pipe Size (in.)	Bare Pipe	Pipe w/ Casing & Air Gap U=1.0	Pipe w/Casing, Air Gap Outside of Insulation: 0.5 in. thick U=0.5	1.0 in. thick U=0.3	1.5 in. thick U=0.23	0 in. thick U=0.18
1.5	27	14	7.4	5.4	4.6	3.9
2.0	29	15	8.3	6.3	5.2	4.6
3.0	31	19	11.	6.5	6.5	5.7
4.0	33	21	12.	9.3	7.6	6.5
6.0	37	26	16.	12.	10.	8.5
8.0	40	30	19.	14.	12.	10.
10.0	44	33	22.	17.	14.	12.
12.0	47	37	24.	19.	15.	13.
14.0	48	38	27.	20.	17.	14.

Source: "MIUS Technology Evaluation, Thermal Energy Conveyance," prepared by Oak Ridge National Laboratory for the U.S. Department of Housing and Urban Development, May 1976.

and, $DHLV_i$ = daily heat loss values from Table 7, Btu/day-ft-°F

L_i = length of pipe section, ft

DM_i = number of days in the month during which hot water is being transferred through the pipe section, days

T_{HW} = temperature of the hot water, °F

T_G = average temperature of the ground for the month, °F

HL_M = total heat loss from the distribution system for the month, Btu

The U values for the example insulation levels in Table 7 are given so that heat losses from extraordinary pipe/insulation configurations can be interpreted from the table using Reference 1 to determine U values.

Example: A hot water distribution system serves three buildings with 2-in. (nominal size) pipelines, 100, 200, and 250 feet/long. The three 2-in. lines are all branches from a 200 foot long, 4-in. main. All lines are uninsulated pipe-within-a-pipe conduits (U=1.0). During the month of May, the heating systems are all turned off early on the 15th of the month (DM=14). The hot water temperature is 210°F and the average ground temperature is 55°F. DHLV for the 2-in. pipe sections is 15. DHLV for the main is 21. Heat loss for the system for the month of May is:

$$HL_m = (210-55)[(15)(100)(14) + (15)(200)(14)+(15)(250)(14) + (21)(200)(14)]$$

$$= 27,000,000 \text{ Btu.}$$

The hot water requirements at all the buildings served by the distribution system can now be summed. These are based on hot water requirements (in Btus) for all buildings on the distribution system. The distribution efficiency of the system is:

$$DIST\text{-}HW_m = \frac{\sum HWD_m}{HL_m + \sum HWD_m}$$

where,

$DIST\text{-}HW_m$ = efficiency of distribution for the system for the month

HL_m = total heat loss from the distribution the month, Btu

$\sum HWD_m$ = the sum of hot water requirements "at the building" for the system for the month, Btu.

Example: For the pipeline system described above, the hot water requirements for the three buildings during the first fourteen days of May are: 52×10^6, 60×10^6, and 74×10^6 Btu. Then the distribution efficiency for the month of May is:

$$DIST\text{-}HW_M = \frac{(52+60+74) \times 10^6}{27.0 \times 10^6 + (52+60+74) \times 10^6}$$

$$= 0.87.$$

B. Chilled Water Pipelines

Heat gains in chilled water distribution systems can be determined in a manner similar to the procedure used in determining losses in hot water systems. Table 8 is used to determine the daily heat gain value for pipeline sections in the distribution system. The total heat gain during a month for the entire chilled water system is:

$$HG_m = (T_G - T_{CW}) \times \sum_i (DHGV_i)(L_i)(DH_i).$$

Table 8. DAILY HEAT GAINS FOR UNDERGROUND CHILLED-WATER PIPE AND CONDUITS PER DEGREE TEMPERATURE DIFFERENCE BETWEEN CHILLED-WATER AND GROUND (BTU/DAY-FOOT-°F)

Nominal Pipe Size (in.)	Bare Pipe	Pipe w/Casing and Air Gap U=1.0	Pipe with Casing, Air Gap Outside of Insulation		
			0.5 in. thick U=0.5	1.0 in. thick U=0.3	1.5 in. thick U=0.23
1.5	27	13	6.6	5.0	4.2
2.0	29	13	7.4	5.6	4.6
3.0	31	16	9.4	7.2	5.8
4.0	33	18	11.0	8.4	6.8
6.0	37	22	14.0	11.0	9.0
8.0	41	25	17.0	13.0	11.0
10.0	44	29	20.0	15.0	13.0
12.0	46	32	22.0	17.0	14.0
14.0	48	33	24.0	18.0	15.0

Source: "MIUS Technology Evaluation, Thermal Energy Conveyance," prepared by Oak Ridge National Laboratory for the U.S. Department of Housing and Urban Development, May 1976.

where,

i designates each unique pipe section

and,

$DHGV_i$ = daily heat gain value from each pipe section from Table 8, Btu/day-ft-°F

L_i = length of pipe section, ft

DH_i = number of days of the month during which chilled water is being transferred through the pipe section

T_{CW} = temperature of the chilled water, °F

T_G = temperature of the ground, °F

HG_m = total heat gain from the distribution system for the month, Btu.

Then the efficiency of the chilled water distribution system is:

$$DIST\text{-}CW_m = \frac{\sum CWD_m}{HG_m + \sum CWD_m}$$

where,

$DIST\text{-}CW_m$ = efficiency of chilled water distribution

HG_m = total heat gain for the month in the distribution system, Btu

$\sum CWD_m$ = the sum of chilled water demands (at the building) for cooling or cold storage, for all building on the system, Btu.

Whenever T_G is less than or equal to T_{CW}, the heat gain or loss for the month is considered to be zero; therefore, the distribution efficiency for that month is 1.00.

For an example of how this procedure is performed, see the examples for the Hot Water Pipelines section above.

C. Steam Pipelines

Heat losses due to distribution of steam in underground pipelines are defined in Table 9 for high-and-low pressure steam pipes and for a variety of pipe sizes. These data are representative of a steam distribution with a variety of insulation levels and can be used as average heat loss data for steam distribution.

Table 9. HEAT LOSSES FOR UNDERGROUND STEAM PIPES (LB OF STEAM/DAY-FT)

Nominal Pipe Size (in)	High* Pressure Line Losses	Low* Pressure Line Losses
2	1.15	0.79
4	1.70	1.15
6	2.14	1.44
8	2.59	1.73
10	3.05	2.04
12	3.48	2.33
14	3.84	2.59
16	4.30	2.88
24	4.82	3.24

*High pressure values used for pipelines where pressure exceeds 50 psi (gauge). Low pressure values for lines 50 psi (gauge) or less.

Source: R. Gallina, Steam Division of Baltimore Gas and Electric Company

The total heat loss for the distribution system for the month is determined by:

$$SL_m = \sum_i (DSTV_i)(L_i)(DM_i)$$

where,

i designates specific pipe sections

and,

SL_m = monthly heat loss in steam system, in equivalent lb of steam

$DSTV_i$ = daily steam loss value from each pipe section from Table 9, lb of steam/day-ft

L_i = length of the pipe section in feet

DM_i = number of days of the month that steam is distributed through this section.

The efficiency of the distribution system can be determined as follows:

$$DIST\text{-}S_m = \frac{\sum SD_m}{SL_m + \sum SD_m}$$

where,

$DIST\text{-}S_m$ = efficiency of the steam distribution system for the month.

$\sum SD_m$ = sum of all steam requirements for the month at all buildings on the system, lb of steam

SL_m = total system losses for the month, lb of steam

For an example of how this procedure is performed, see the examples for the Hot Water Pipelines section above.

XII. SUMMATION OF ENERGY USES

There are two summation procedures outlined in this chapter. They are: (1) the determination of all energy uses in one building, and (2) the summation of all energy uses for an installation or group of buildings. In addition, some guidelines for the estimation of energy use in buildings other than the five types of buildings specifically referred to in the preceding chapters of this supplement are given.

A. Energy Consumption of a Building

Summation of energy consumptions for a building can be performed for any time period desired, i.e., daily, monthly, annually, etc. Care must be taken to insure that all energy consumption values added together are representative of the same time period. Notice that in Chapters II and III heating and cooling energy use is determined on a monthly basis, while in Chapters IV through IX, the energy consumption due to the various activities is determined on a daily basis except in Chapter VIII (Cold Storage) and in Chapter VII, Section C (Laundries) where energy use is determined on a monthly basis.

When all energy use is desired on a daily basis, monthly consumptions should be divided by the number of days in the appropriate month. When energy use calculations are desired for a month or series of months, daily consumptions should be multiplied by the number of days in the month or series of months. When annual values are desired, multiply daily values by 365 (or 366 for a leap year).

Energy consumption summation for any building is done by disaggregating energy uses according to the fuel (or energy) source that crosses the building boundary and totaling for each source. That is, electricity, coal, oil, gas, steam, hot water, and chilled water consumptions are computed by defining the fuel source for each energy use activity in the building.

Electric heating and cooling consumptions must be converted to kilowatt-hours before being added to other electricity uses (1 Kw-hr = 3413 Btu). Electricity, coal, oil, and gas usage can now be accumulated for the entire building and total on-site consumption of these fuels is obtained. Steam, hot water, or chilled water must be traced to their sources of generation. The generation plant's efficiency and fuel type must be identified. Distribution efficiency can be determined according to Chapter XI. Then the steam, hot water, or chilled water generation plant's fuel consumption attributable to the building of study can be determined according to the following equation:

$$\text{Fuel Consumption} = \frac{\text{Energy Consumption in Building}}{\text{Distribution Efficiency} \times \text{Generation Efficiency}}$$

Fuel usage at steam, hot water, or chilled water generation plants (on-base energy use) can now be added to the in-structure energy use of the appropriate fuel type. The result for a building is a series of five numbers which represent energy use in the building of five fuel source types (electricity, coal, oil, gas, and other). Any number of these fuel type totals may be zero. When actual heating values of the fuels consumed are not known, coal, oil, and gas consumption can be converted into physical measures with the following conversion factors:

1 gallon #6 fuel oil	=	148,000 Btu
1 gallon #2 fuel oil	=	142,000 Btu
1 standard ton of coal	=	25,000,000 Btu
1 cubic foot of gas	=	1,000 Btu

Tables A, B, C, and D can be used for summation of a building's energy use.

B. Energy Consumption of an Installation

The total energy use by all buildings on an installation within the five categories considered throughout this manual (single-family detached housing, townhouse residences, barracks, administration/office buildings, and commissaries) can be determined with the EUI Method. However, adding up the electricity, coal, oil, gas, and other fuels used in all buildings of these types for an installation does not produce total installation energy use. Buildings of other types must also be considered. The energy use in such buildings can be estimated by using the method presented in this manual by assigning each of these buildings to a category nearest to its use and occupancy type. Some examples are: a classroom building might be considered as an administration/office building because its

occupancy schedule would be similar; a warehouse might be considered an administration/office building with a low set-point temperature and reduced occupancy. Also, a dining hall could be categorized as a barrack with mess hall, at least for cooking energy use. Other buildings must be categorized according to the judgment of on-base personnel, utilizing their knowledge of base operations to approximate total energy consumption by an installation.

To summarize building energy consumption for an entire installation, the following procedure may be used. Assign buildings to categories of similar type and occupancy as shown in Table D. Perform the EUI calculation for one building of each category and multiply the results by number of buildings in that category. When similar buildings of different size are in one category, normalize the predicted energy consumption to units per square foot and multiply by the total area of that category. Table D can be used for monthly or annual accounting of energy prediction.

Table A. HEATING ENERGY SUMMATION

Building____________ Equivalent "U" Value____________

Net Floor Area____________ Volume____________

Building Envelope Area____________ Window Area____________

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
(1) Heating Degree Days												
(2) QH_1												
(3) $CH_1 \times CON \times A_{total}$												
(4) FH_1												
(5) $1 + FH_1(T - 72)$												
(6) QH_{env} $(1 \times 10^4 \times 2 \times 3 \times 5)$												
(7) V (mph)												
(8) I (cfm)												
(9) QH_2												
(10) FH_2												
(11) $1 + FH(T - 72)$												
(12) $I + V_r$												
(13) QH_{in} $(9 \times 11 \times 12)$												

Table A (cont)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
(14) $CR_{2,4}$												
(15) IR												
(16) Days (N)												
(17) A_{WD} x 3.687												
(18) QH_{rad}(14x15x16x17)												
(19) $A_fU_f + A_wU_w$												
(20) CH_F												
(21) T_g												
(22) $(T - T_g)$												
(23) QH_{floor}(19x20x22)												
(24) QH_o												
(25) GH_I												
(26) QH_{total}(6+13-18+23-25)												
(27) GH_{heat}												

Table B. COOLING ENERGY SUMMATION

Building______________________ Equivalent "U" Value______________________

Net Floor Area______________________ Volume______________________

Building Envelope Area______________________ Window Area______________________

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
(1) CDD's												
(2) QC_1												
(3) FC_1												
(4) $1 + FC_1[T-72]$												
(5) $A_t \times CC_1 \times K$												
(6) QC_{env} (1x2x4x5)												
(7) V												
(8) I												
(9) DICDD												
(10) QC_2												
(11) FC_2												
(12) $1 + FC_2[T-72]$												
(13) $I + V_r$												
(14) QC_{inf} (10x12x13)												

Table B (Cont)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
(15) $CR_{1,3}$												
(16) IR												
(17) Days (N)												
(18) $A_t \times 3.687$												
(19) QC_{rad}(15x16x17x18)												
(20) CC_F												
(21) T_g												
(22) $T - T_g$												
(23) $A_fU_f + A_wU_w$												
(24) QC_{floor}(20x22x23)												
(25) QC_o												
(26) QC_I												
(27) QC_{total}(6+14+19-24-26) QC_{total}												
(28) (1000)(EER)(E_{dist})												
(29) Q_{cool} (kW-hr/mo)												

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Table C. TABLES FOR BUILDING ENERGY SUMMATION

Building No. _____

Month	Q_{heat}	Q_{cool}	Ltgt	Cooking	DHW	Lndy	CdST	Eq/AP	Addl	TOTAL
JAN										
FEB										
MAR										
APR										
MAY										
JUN										
JUL										
AUG										
SEP										
OCT										
NOV										
DEC										
TOTAL										

Fuel Source

Activity	Electricity	Oil	Gas	Steam	Hot Water	Chilled Water	Coal	Other
Q_{heat}								
Q_{cool}								
Ltgt								
Cooking								
DHW								
Lndy								
CdST								
Eq/AP								
Addl								
Total								

Table D1. RECOMMENDED TABLE FOR INSTALLATION ENERGY SUMMATION

				Fuel Source							
Category	Building Description	No. of Bldgs.	Total Area	Electricity	Oil	Gas	Steam	Hot Water	Chilled Water	Coal	Other
A1	Family Housing - Single-1957	46									
A2	Family Housing - Single-1964	98									
B1	Family Housing - Multi-1972	251									
C1	178 MN EM BK w/mess-1956	11									
C2	141 MN EM BK wo/mess-1972	13									
C3	30 MN EM BK wo/mess-1942	44									
D1	Admin Bldg - 1942	3									
D2	Admin Bldg - 1964	2									
E1	Commissary - 1972	1									
01	Training Bldgs - 1972	6									
02	Training Bldgs - 1962	3									

Table D2. SAMPLE RECOMMENDED TABLE FOR INSTALLATION ENERGY SUMMATION

				Fuel Source							
Category	Building Description	No. of Bldgs.	Total Area	Electricity	Oil	Gas	Steam	Hot Water	Chilled Water	Coal	Other

XIII. BASIC PROCEDURES USED IN COMPUTATION OF ENERGY USAGE

A. Heating

Building structural data and monthly heating degree days are used to calculate the monthly heating energy use. The calculations are based on heat loss or gain due to the following items:

- Exterior envelope
- Infiltration/ventilation
- Solar radiation
- Floors and underground walls
- Internal heat generation
- Interior walls

The total heating energy usage is the sum of the above loads divided by the heating system efficiency.

B. Cooling

Building structural data, monthly cooling degree days and monthly discomfort index cooling degree days are used to calculate the cooling energy use. The discomfort index cooling degree day is used in calculating the infiltration cooling load component and the cooling degree day is used to calculate the following load components:

- Exterior envelope
- Solar radiation
- Floors and underground walls
- Internal heat generation
- Interior walls

The total cooling energy use is the sum of the component cooling loads, divided by the overall C.O.P. of the building cooling system.

C. Lighting

The electricity consumption due to lighting is dependent upon the building occupancy and floor area. The lighting energy consumption is determined by multiplying the usage rate by the proper occupancy correction factor and floor area for each building.

D. Cooking

Cooking energy consumption in the family housing unit is determined based on a family of four in each unit and the type of range (electric or gas) used. In the barracks, cooking energy consumption is determined from the number of meals served per day or from the total number of residents in the barracks.

E. Hot Water Heating

The energy consumption due to residential water heating is primarily a function of the type of fuel used in the water heater. For other building types, the consumption is a function of the building occupancy. For these buildings, the hot water heating energy consumption is determined by multiplying the number of occupants by the appropriate value given in the text.

F. Laundry

Laundry energy consumption in the housing units is determined by multiplying the building occupancy by the Btu usage rate per occupant. For base lanudries, energy consumption is determined by multiplying the number of articles processed each month by the Btu usage per article.

G. Cold Storage

Cold storage energy consumption is calculated from the capacity of the refrigeration system and the load ratio for the month.

H. Electrical Equipment and Appliances

Equipment and appliance electrical energy use for family housing units is determined by summing the energy usage rates of the major electric appliances given in the text. Equipment and appliance usage in other buildings is determined on either a per resident or floor area basis.

I. Pipeline Losses

Pipeline losses are determined by using the average monthly ground temperature, the temperature of the hot or chilled water, the length of the pipe, and the nominal pipe size.

XIV. REFERENCES

1. ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., New York, 1972, pp. 347-374.

2. Kusuda, T., "Feasibility Study for Mathematical Representation of Coincident Weather Data as Related To Heating and Cooling Load Calculations of Buildings," NBS Report 10036, National Bureau of Standards, U.S. Department of Commerce, May, 1969.

3. "Engineering Weather Data, TM 5-785 (also AFM 88-8, Ch. 6, and NAVFAC P-89), Departments of the Air Force, the Army, and the Navy, 15 June 1967.

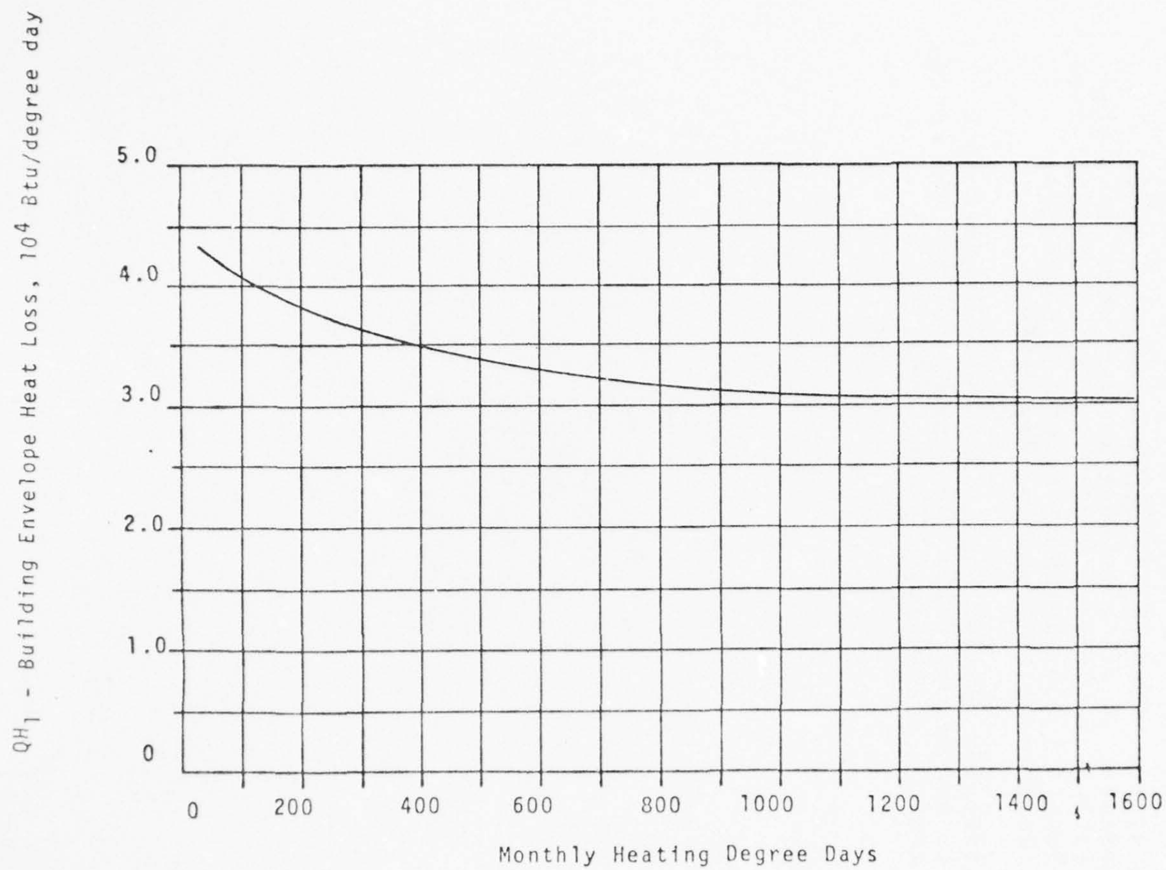

Figure 1-A. Building Envelope Heating Load As a Function of Heating Degree Days Per Month

HEATING

TOWN HOUSE

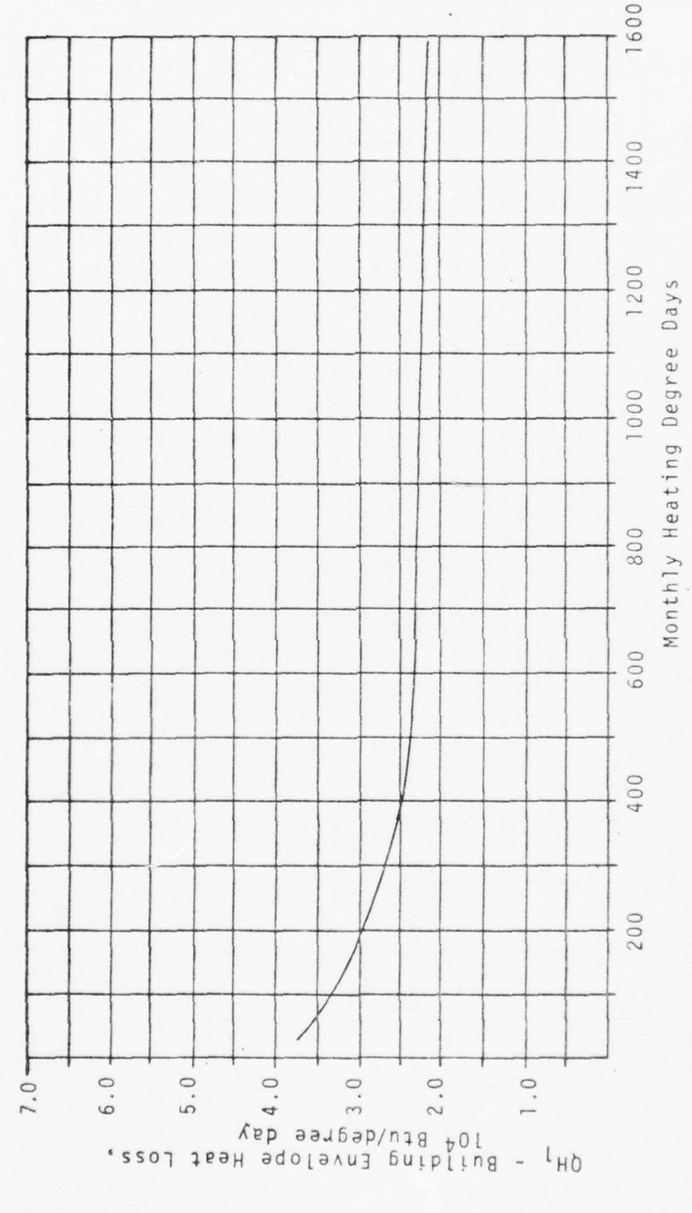

Figure 1-B. Building Envelope Heating Load As a Function of Heating Degree Days Per Month

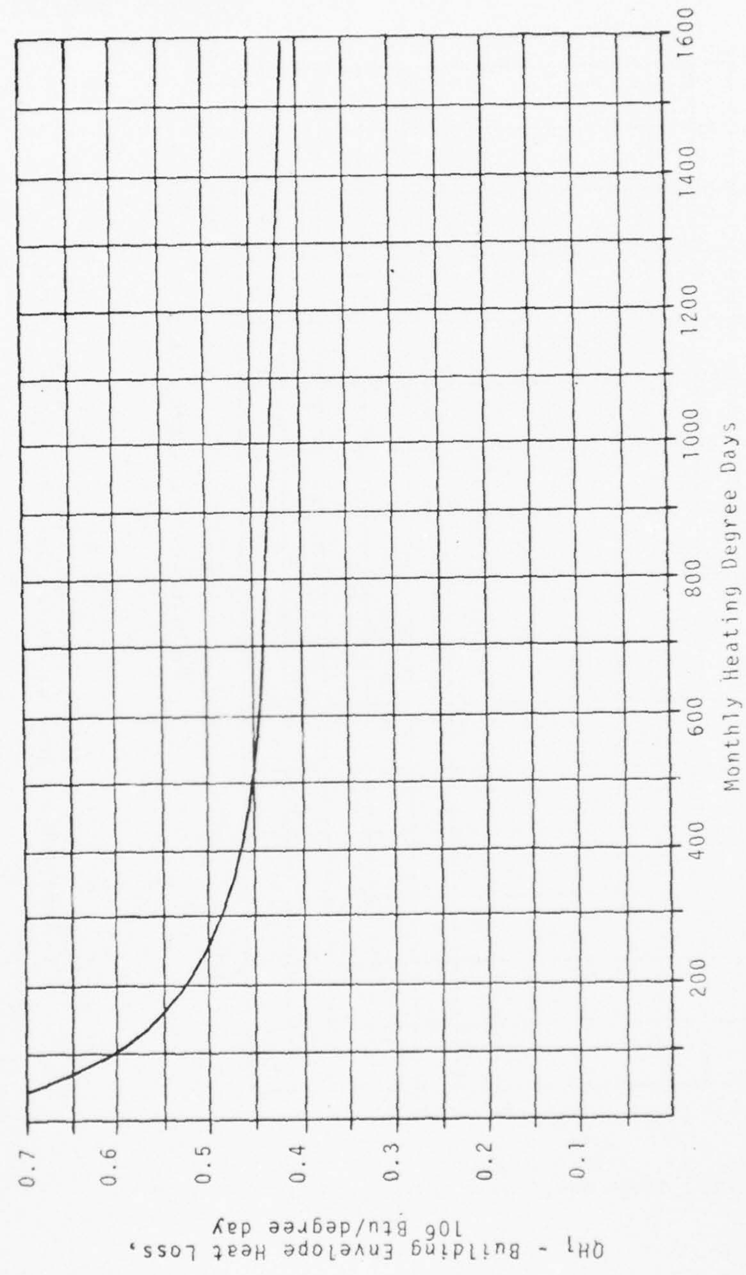

Figure 1-C. Building Envelope Heating Load As a Function of Heating Degree Days Per Month

HEATING

ADMINISTRATION

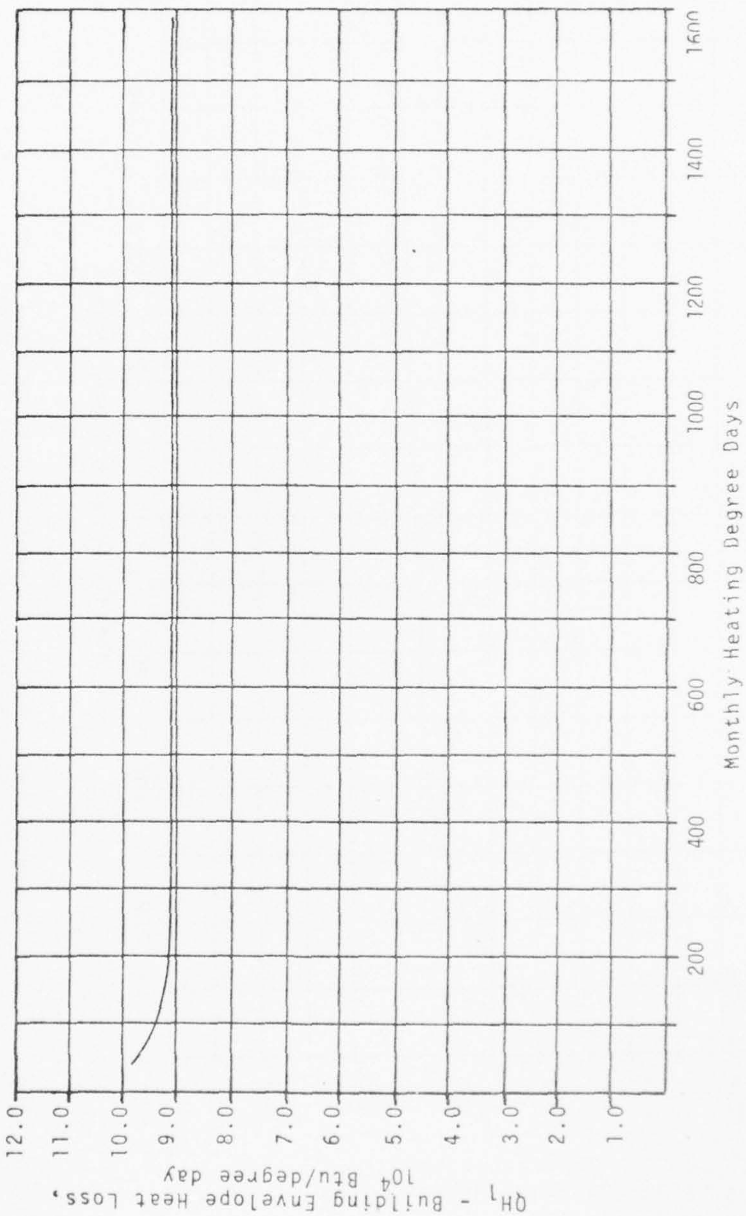

Figure 1-D. Building Envelope Heating Load As a Function of Heating Degree Days Per Month

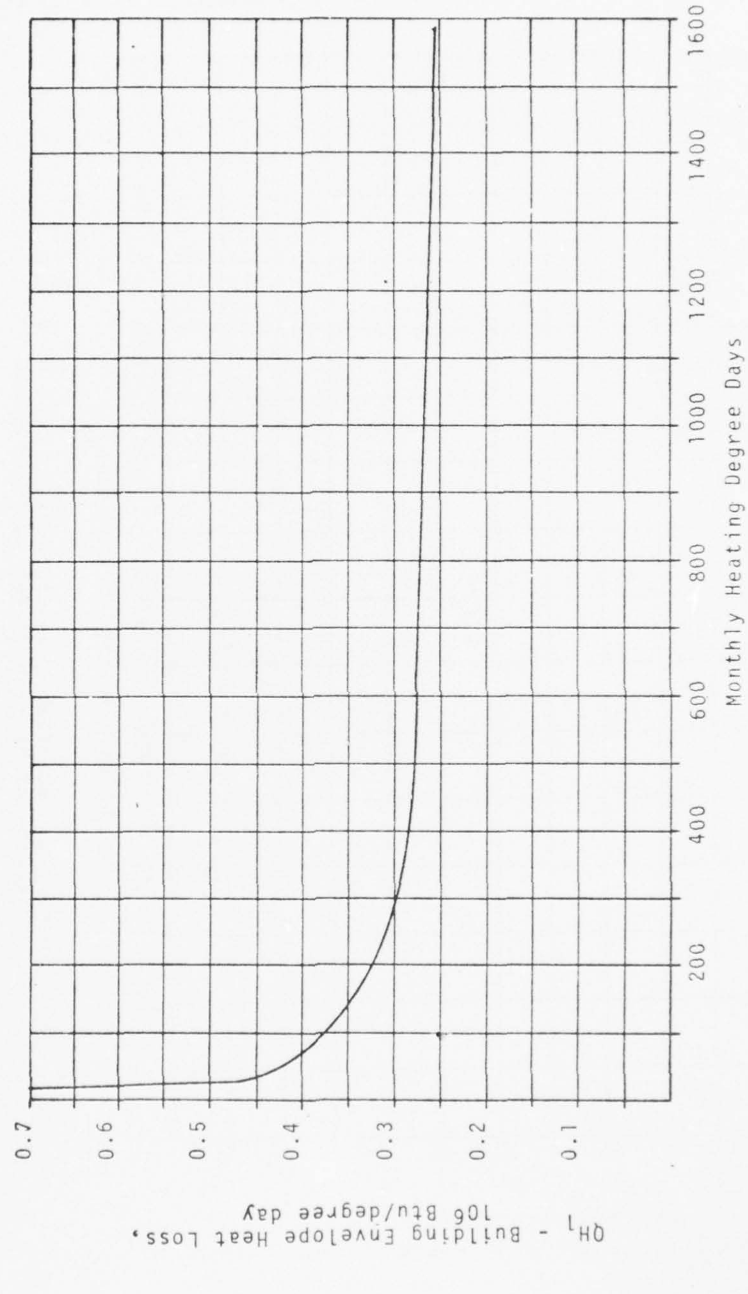

Figure 1-E. Building Envelope Heating Load As a Function of Heating Degree Days Per Month

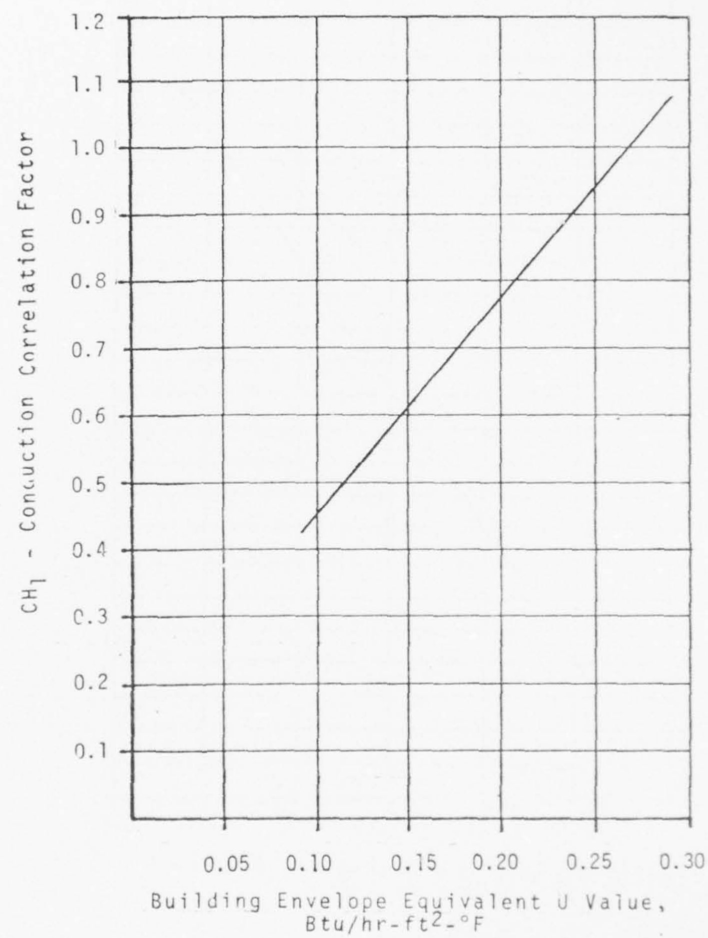

Figure 2-A. Building Envelope Heating Load Correlation With Building Equivalent U Value

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ENERGY UTILIZATION INDEX METHOD FOR PREDICTING BUILDING ENERGY --ETC(U)
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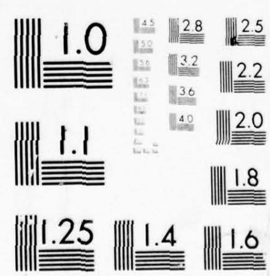

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NATIONAL BUREAU OF STANDARDS-1963-A

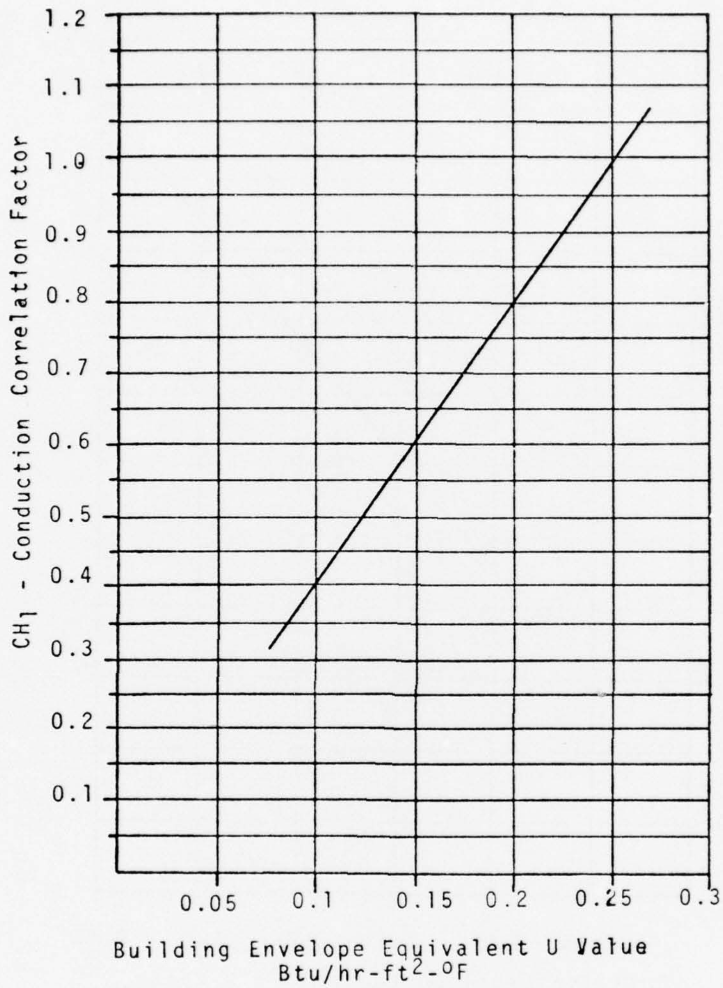


Figure 2-B. Building Envelope Heating Load Correlation With Building Equivalent U Value

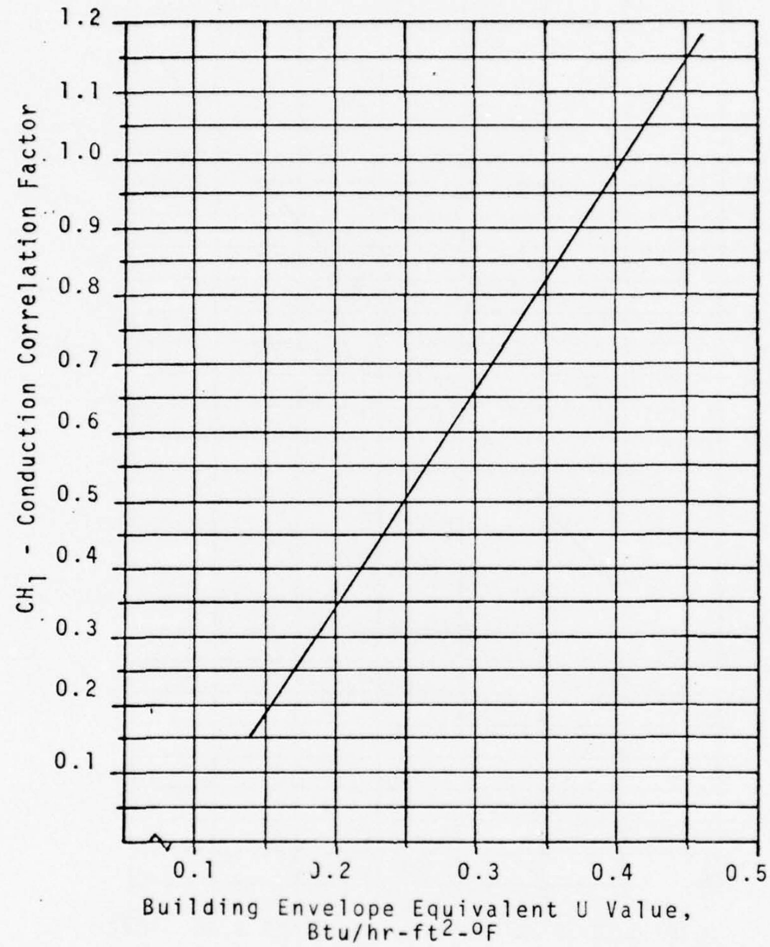


Figure 2-C. Building Envelope Heating Load Correlation With Building Equivalent U Value

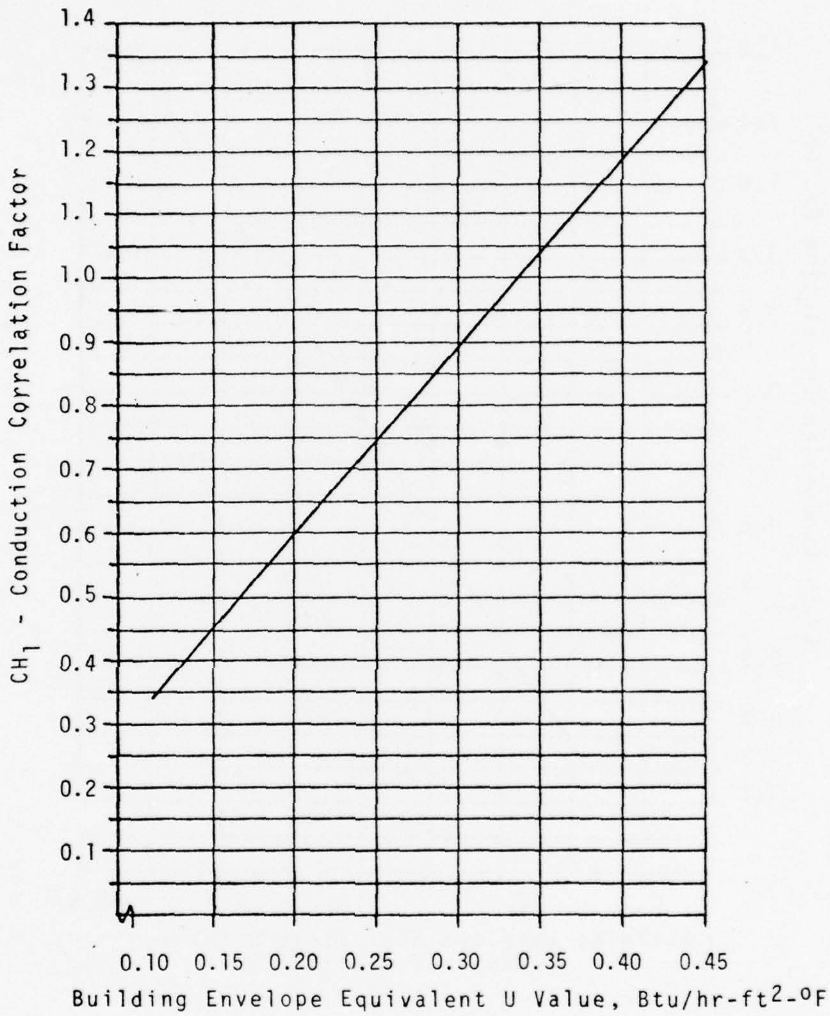


Figure 2-D. *Building Envelope Heating Load Correlation With Building Equivalent U Value*

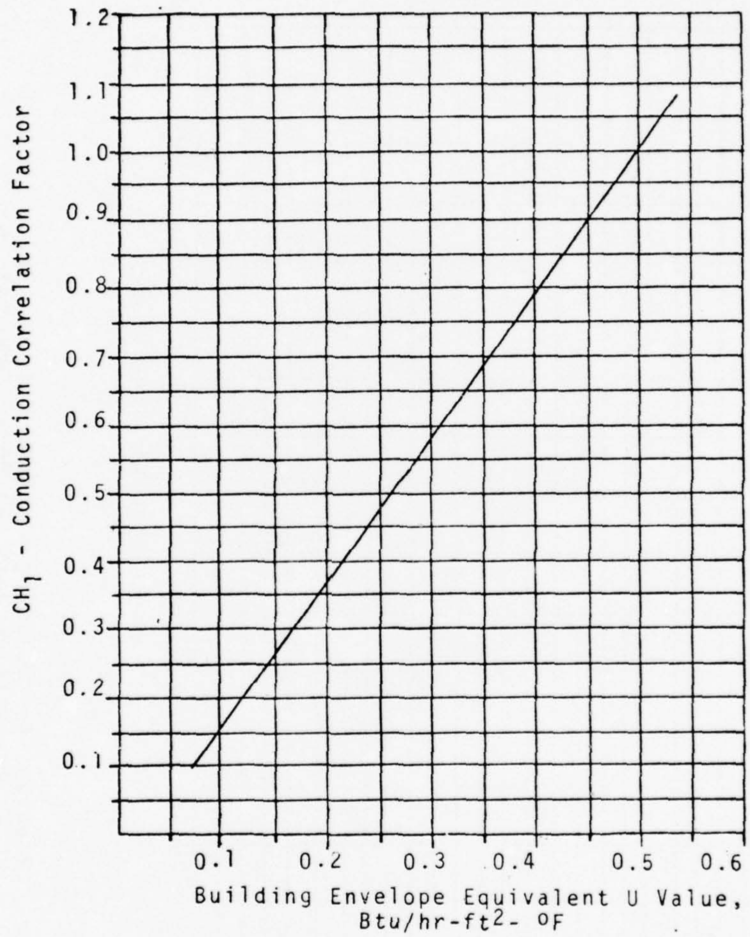


Figure 2-E. Building Envelope Heating Load Correlation With Building Equivalent U Value

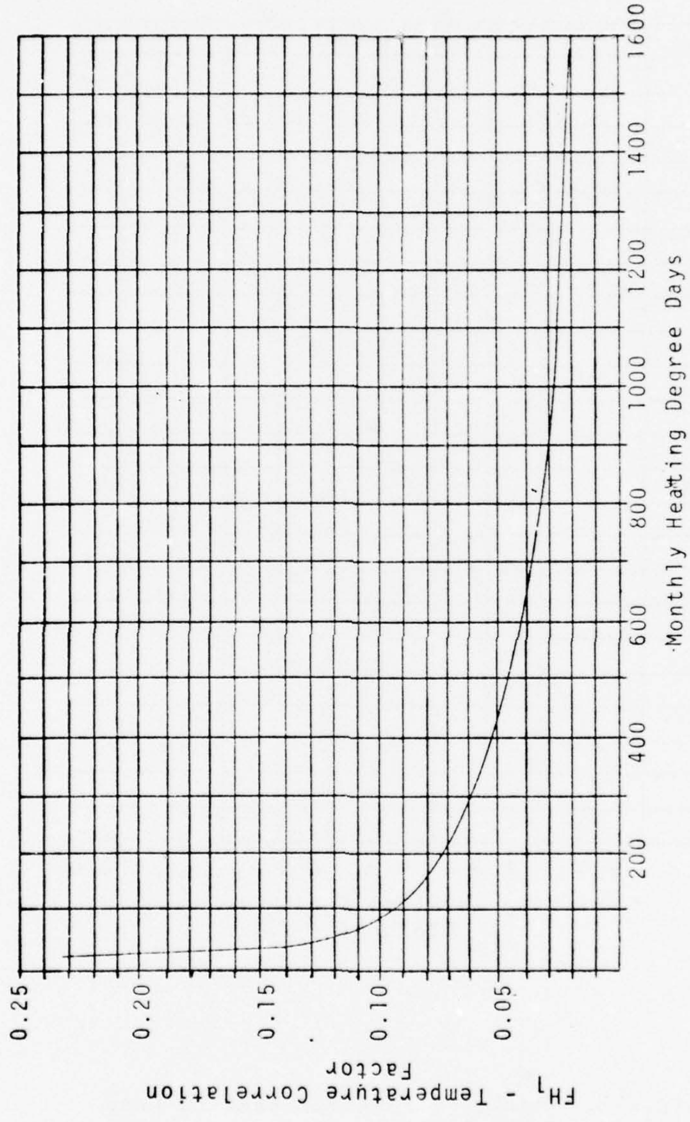


Figure 3-A. Building Envelope Heating Load Correlation With Set-Point Temperature

HEATING
TOWN HOUSE

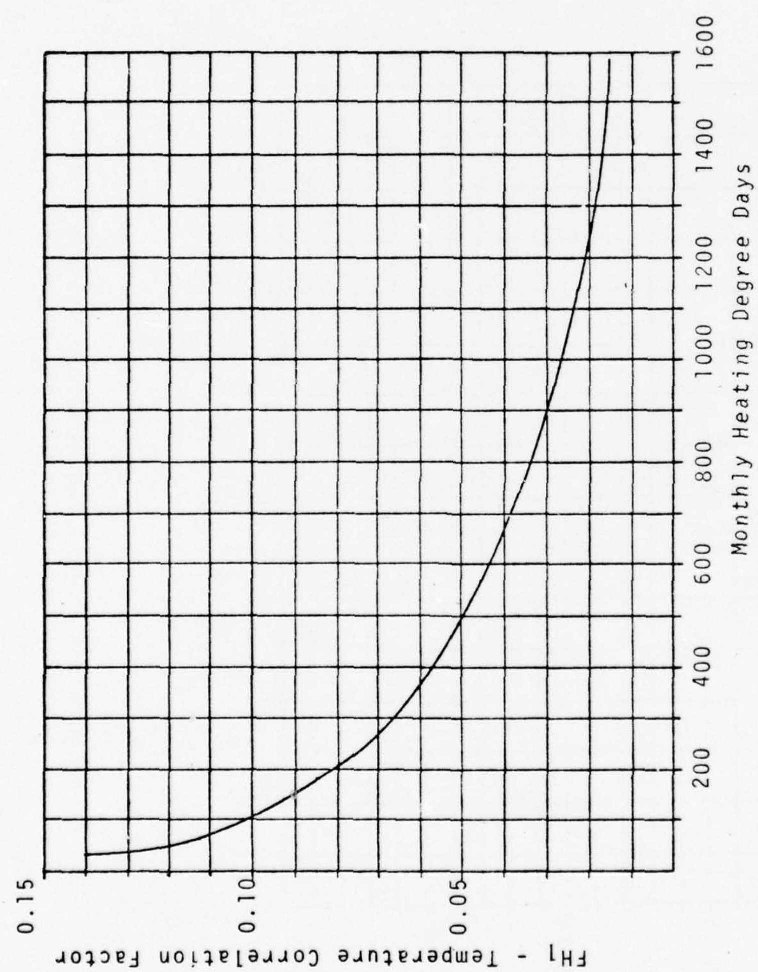


Figure 3-B. Building Envelope Heating Load Correlation With Set-Point Temperature

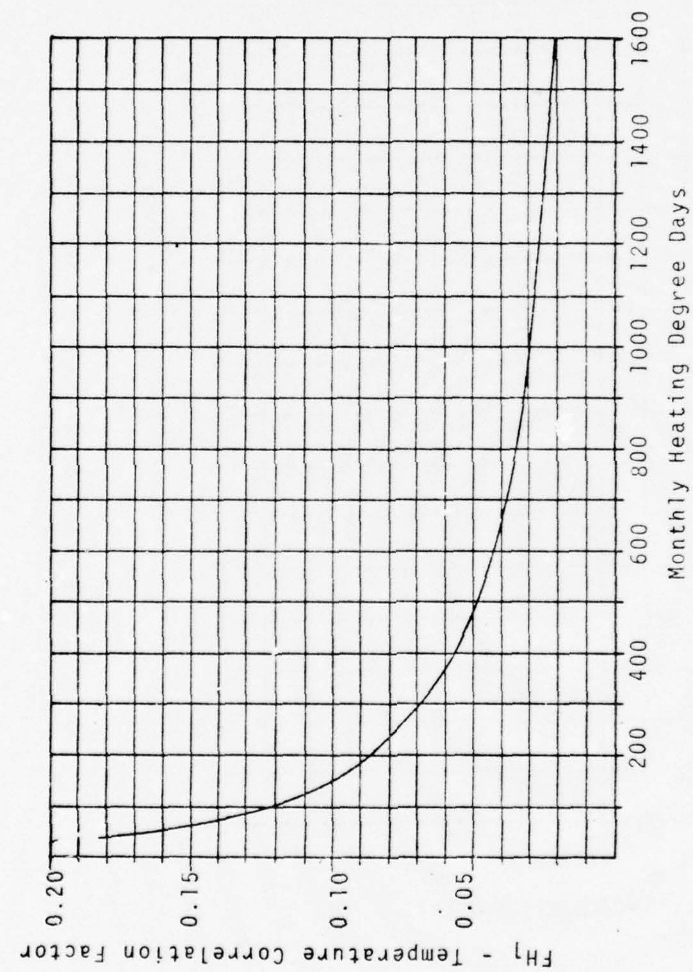


Figure 3-C. Building Envelope Heating Load Correlation With Set-Point Temperature

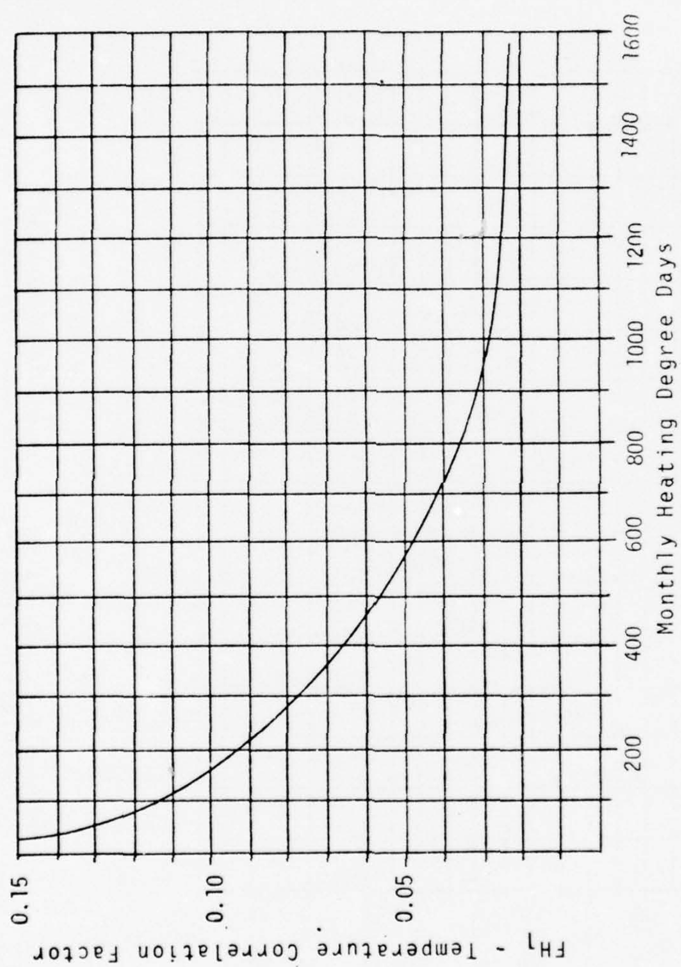


Figure 3-D. Building Envelope Heating Load Correlation With Set-Point Temperature

HEATING
COMMISSARY

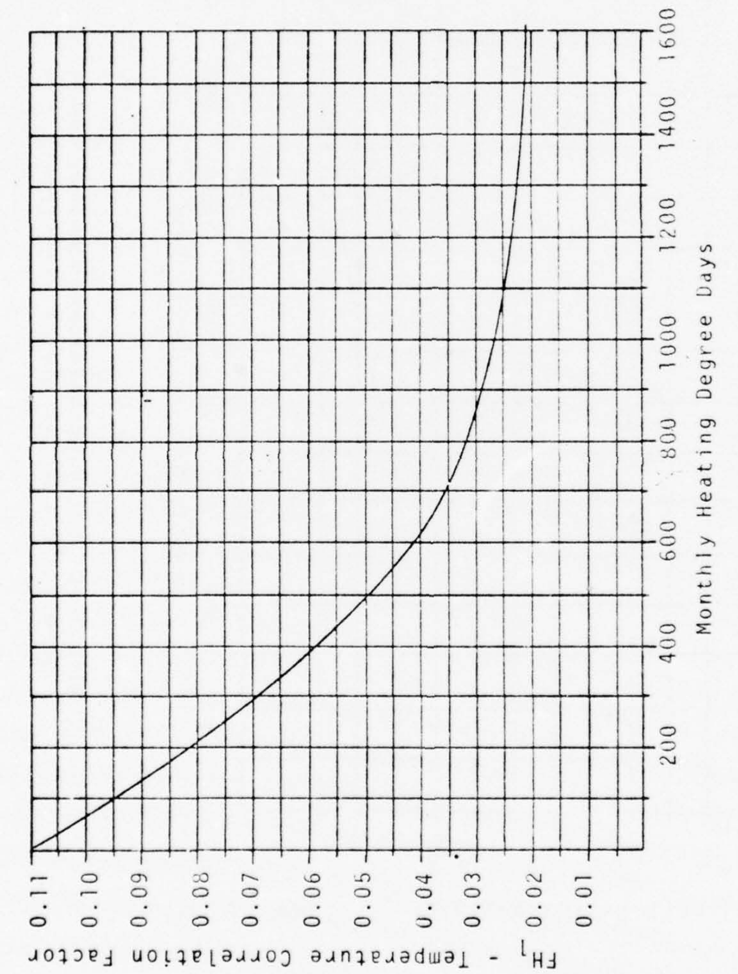


Figure 3-E. Building Envelope Heating Load Correlation With Set-Point Temperature

HEATING
ALL BUILDINGS

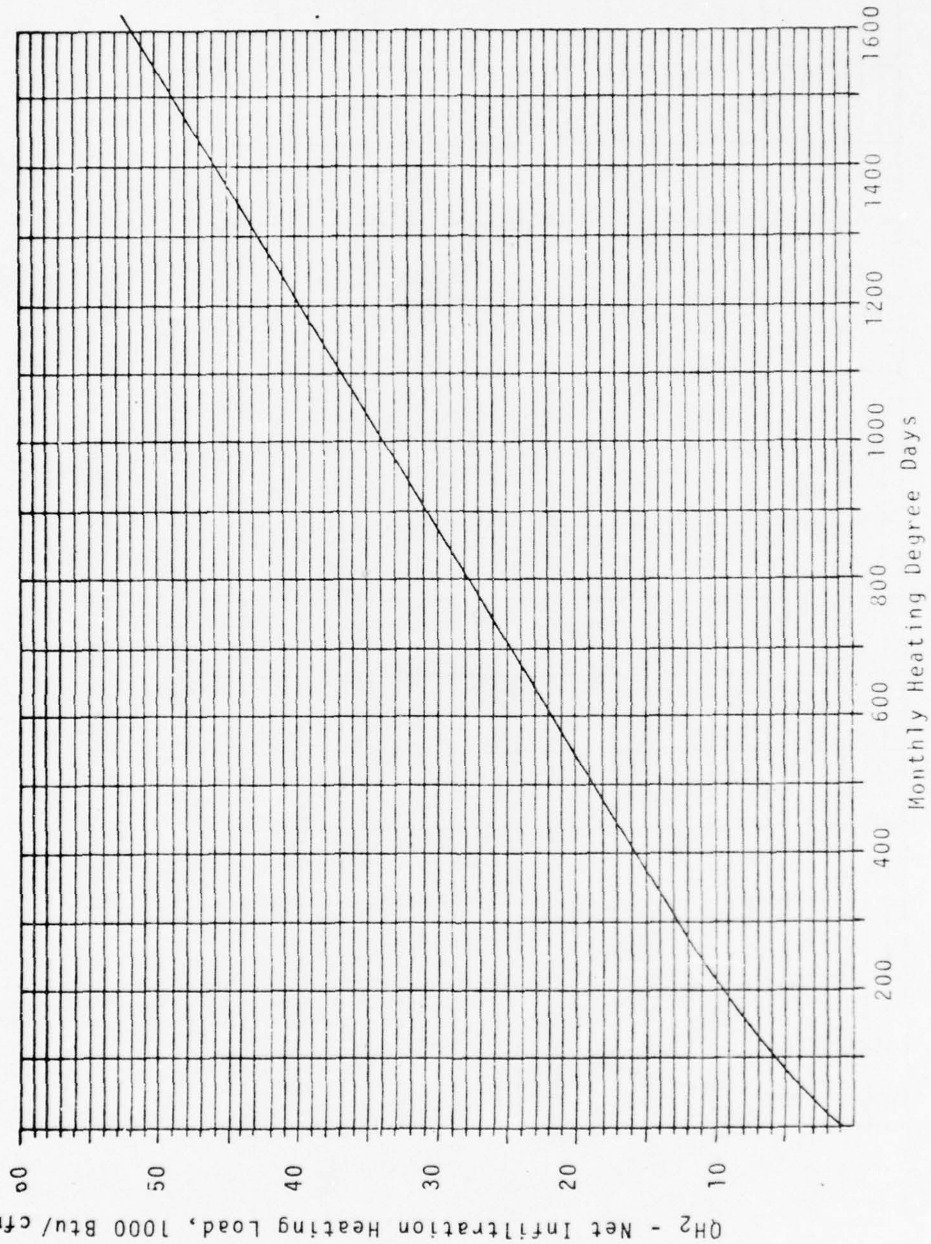


Figure 4-A,B,C,D,E. Infiltration Heating Load As A Function of Heating Degree Days Per Month

HEATING
ALL BUILDINGS

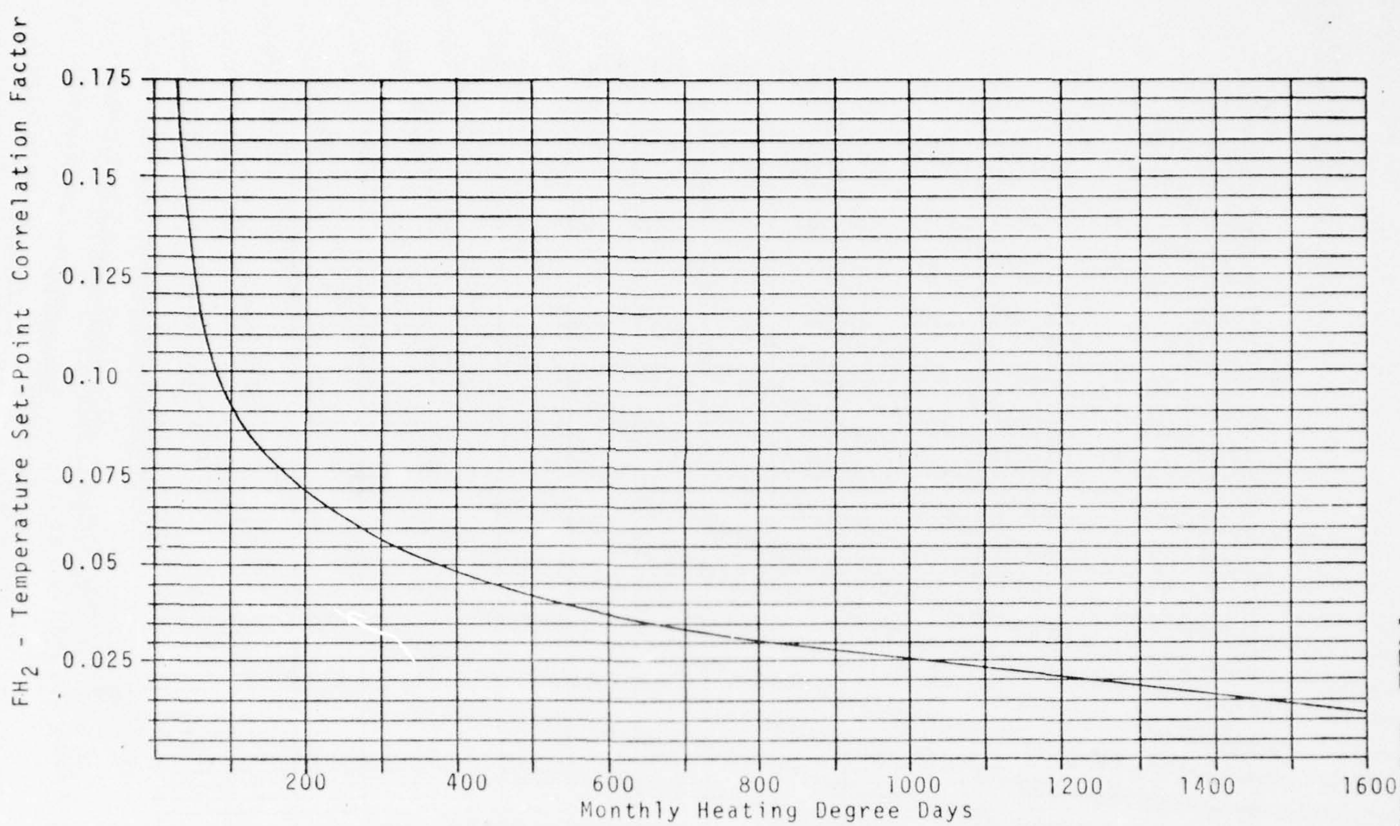


Figure 5-A,B,C,D,E. Infiltration Heating Load Correlation With Set-Point Temperature

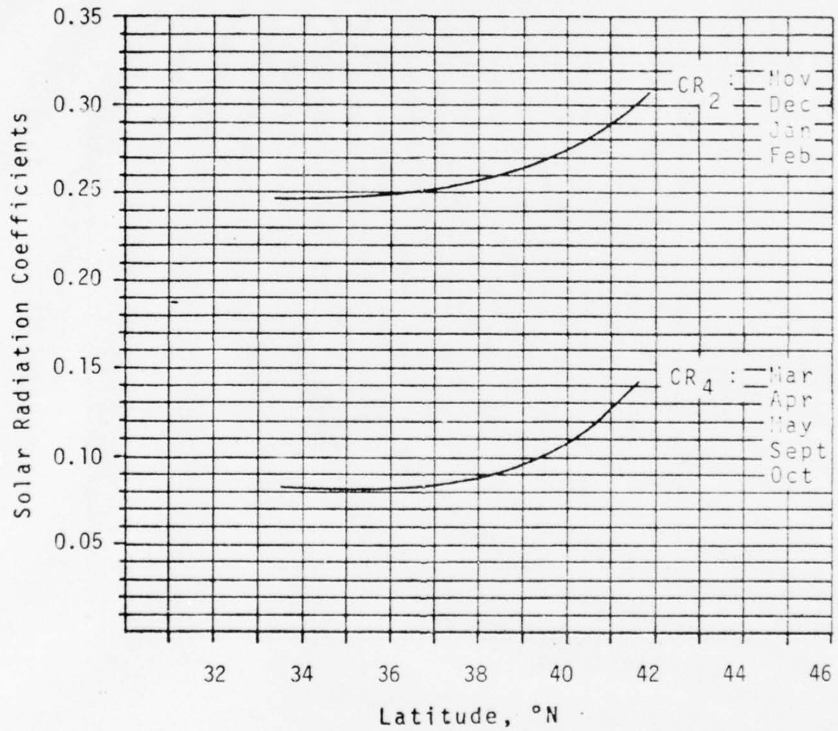


Figure 6-A,B. Seasonal Solar Radiation Correlation Coefficient As a Function of Latitude

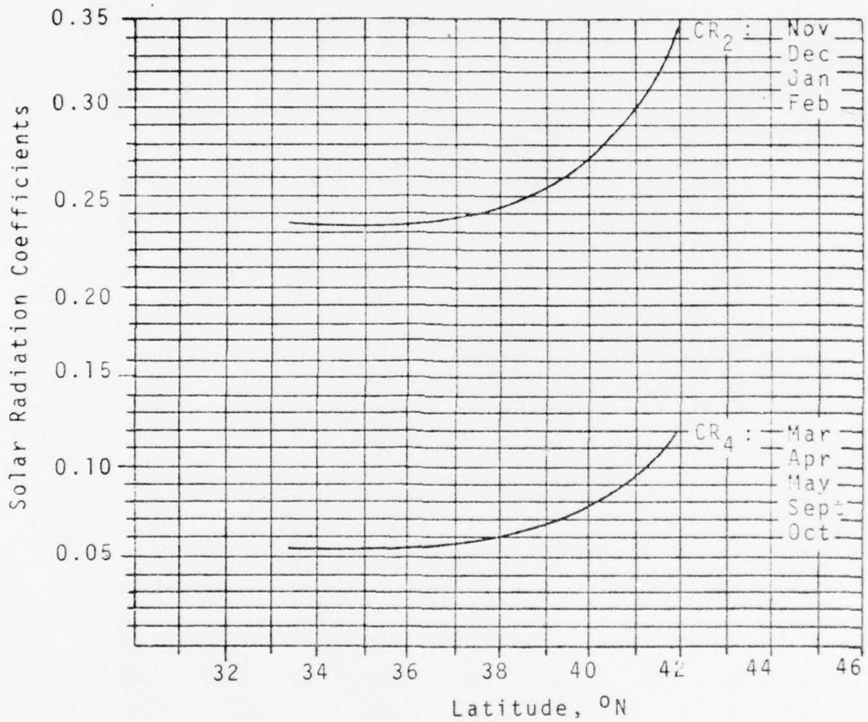


Figure 6-C. Seasonal Solar Radiation Correlation Coefficient As a Function of Latitude

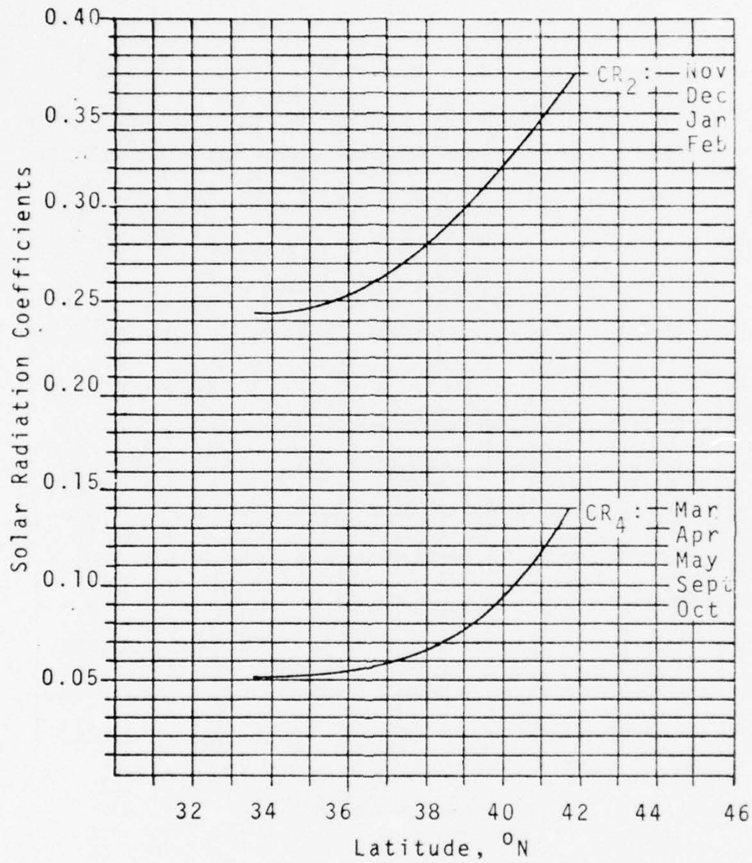


Figure 6-D. Seasonal Solar Radiation Correlation Coefficient As a Function of Latitude

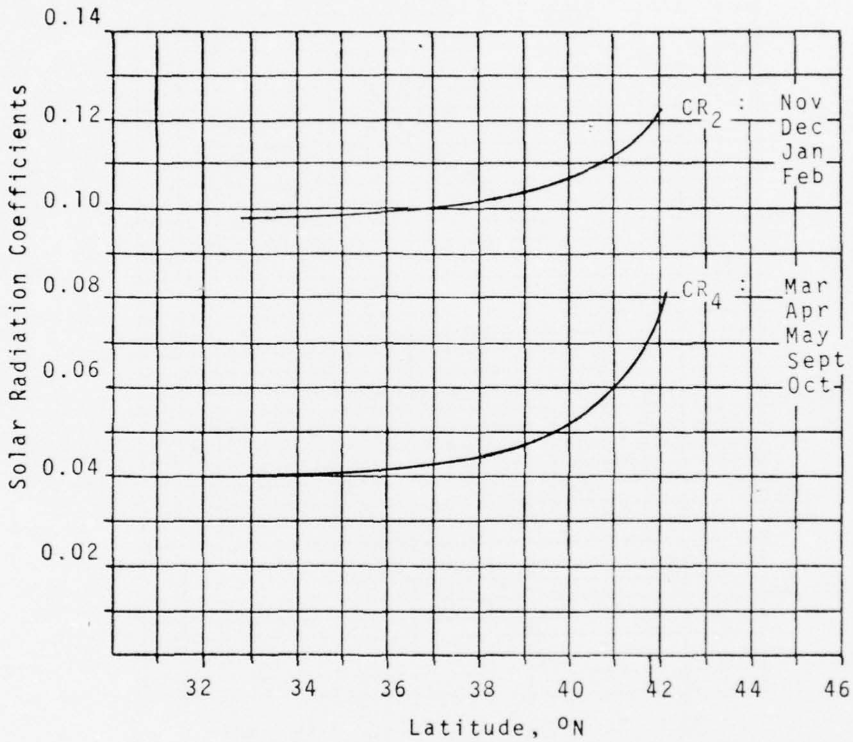


Figure 6-E. Seasonal Solar Radiation Correlation Coefficient As a Function of Latitude

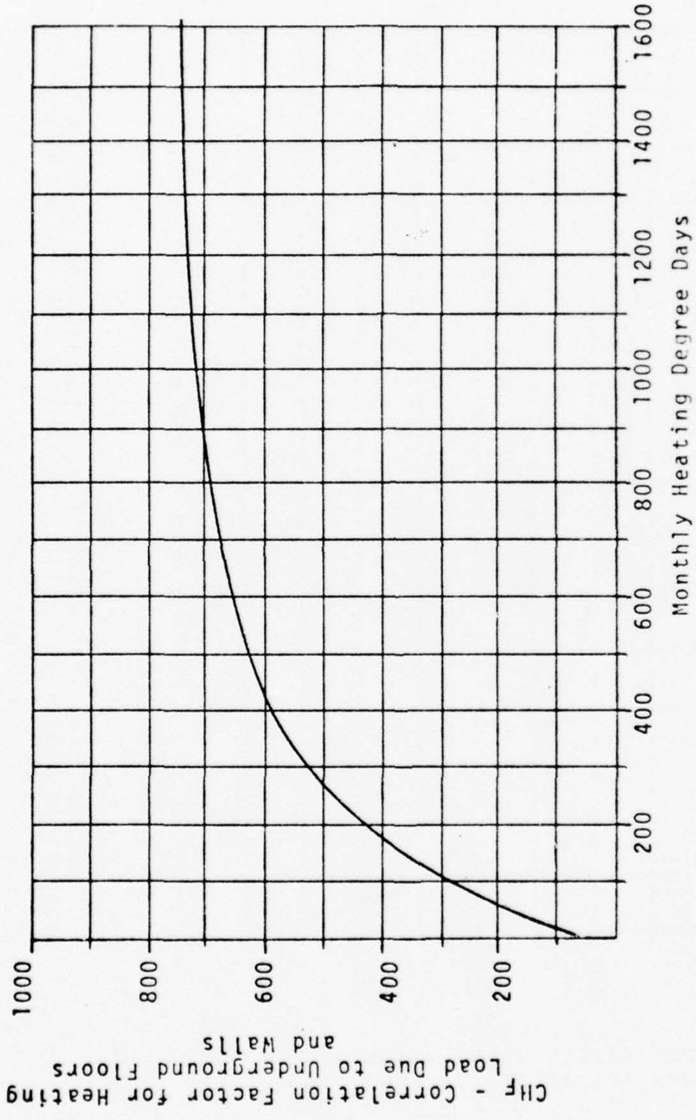


Figure 7-A,B,C. Correlation Factor for Heating Load Due to Underground Floors and Walls as a Function of Heating Degree Days

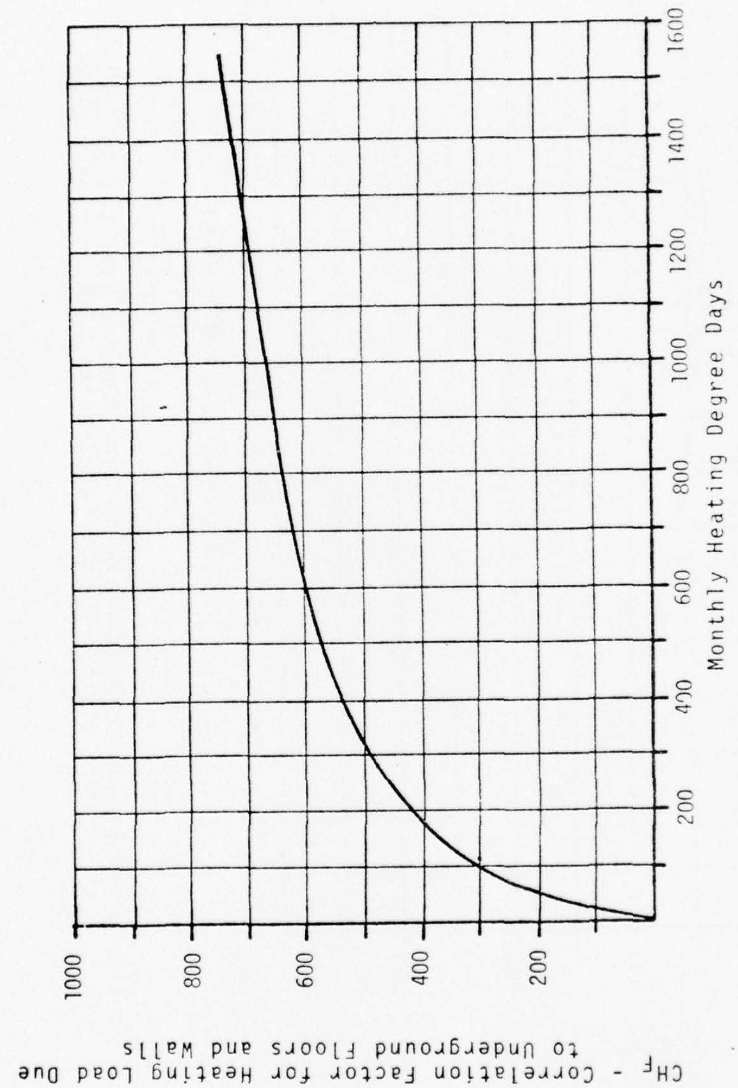


Figure 7-D. Correlation Factor for Heating Load Due to Underground Floors and Walls As a Function of Heating Degree Days

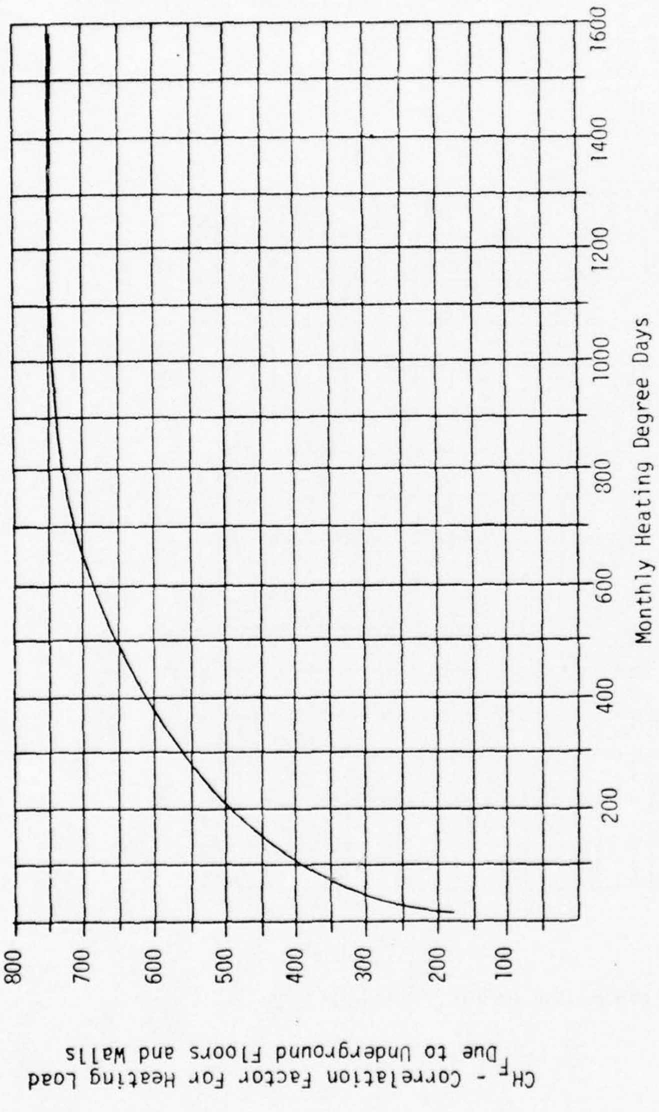


Figure 7-E. Correlation Factor for Heating Load Due to Underground Floors and Walls As a Function of Heating Degree Days

HEATING
SINGLE-FAMILY
TOWN HOUSE

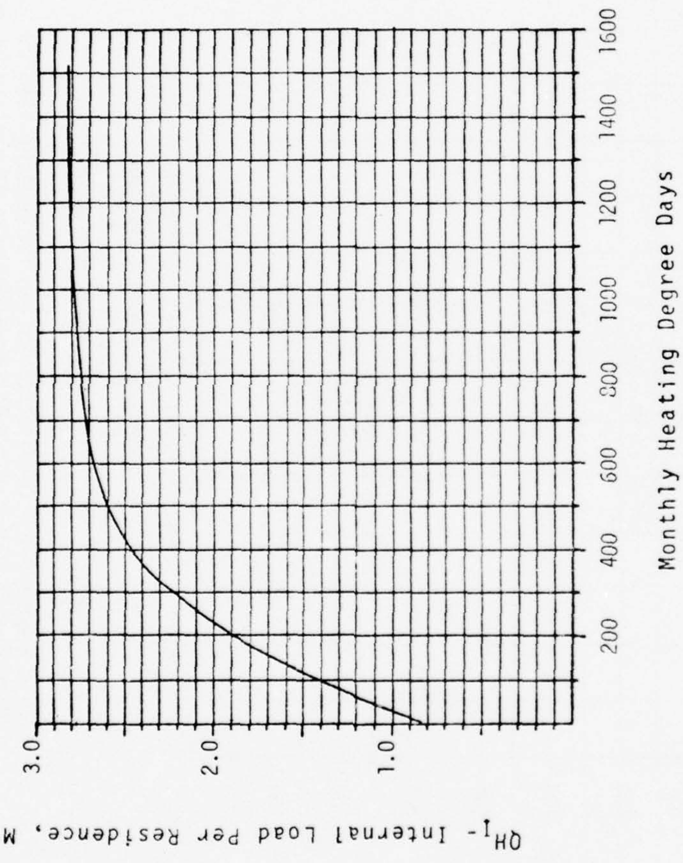


Figure 8-A,B. Internal Heat Generation During Heating Season
As a Function of Heating Degree Days

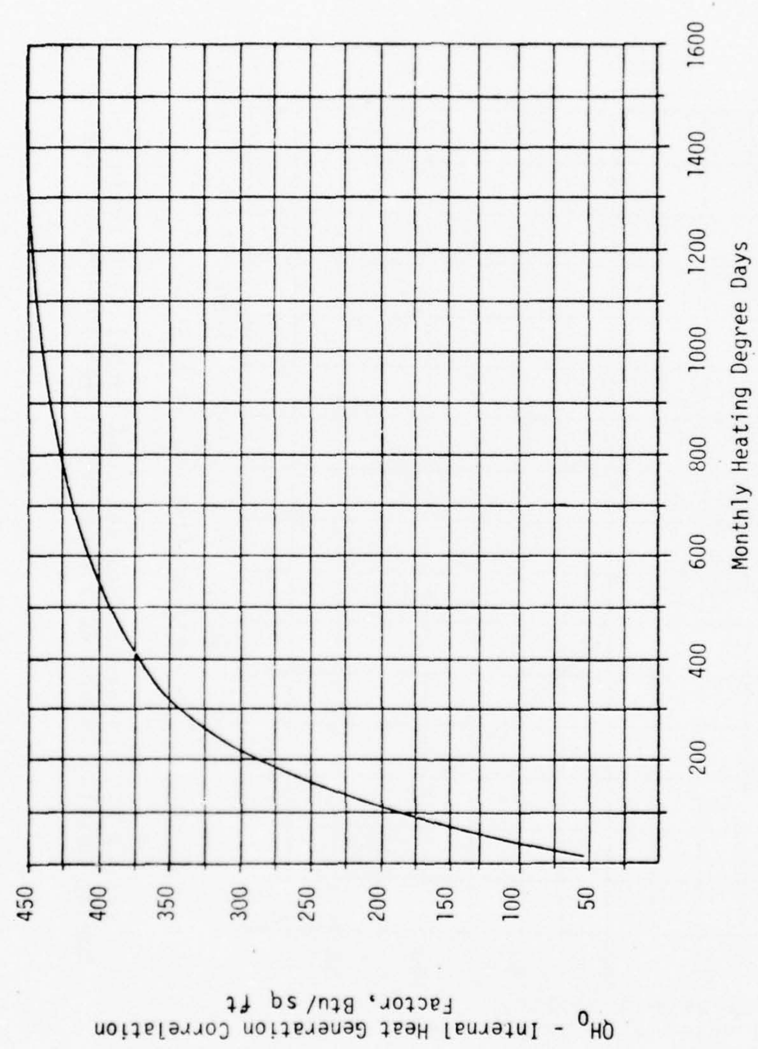


Figure 8-C. Internal Heating Load Correlation Factor During Heating Season As a Function of Heating Degree Days

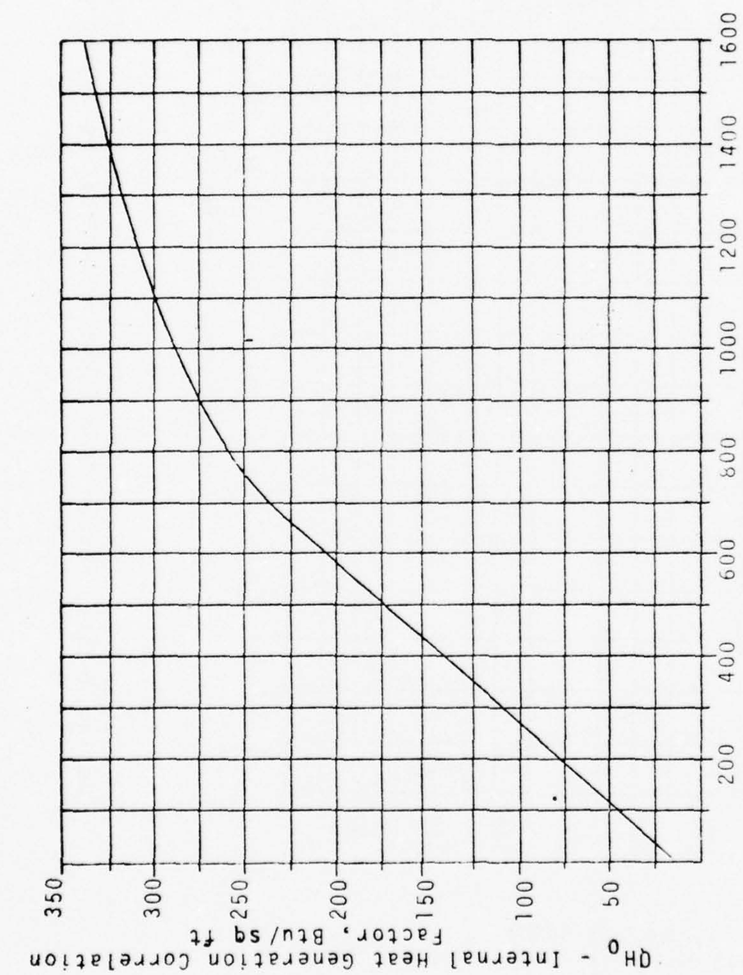


Figure 8-D. Internal Heating Load Correlation Factor During Heating Season As a Function of Heating Degree Days.

HEATING

COMMISSARY

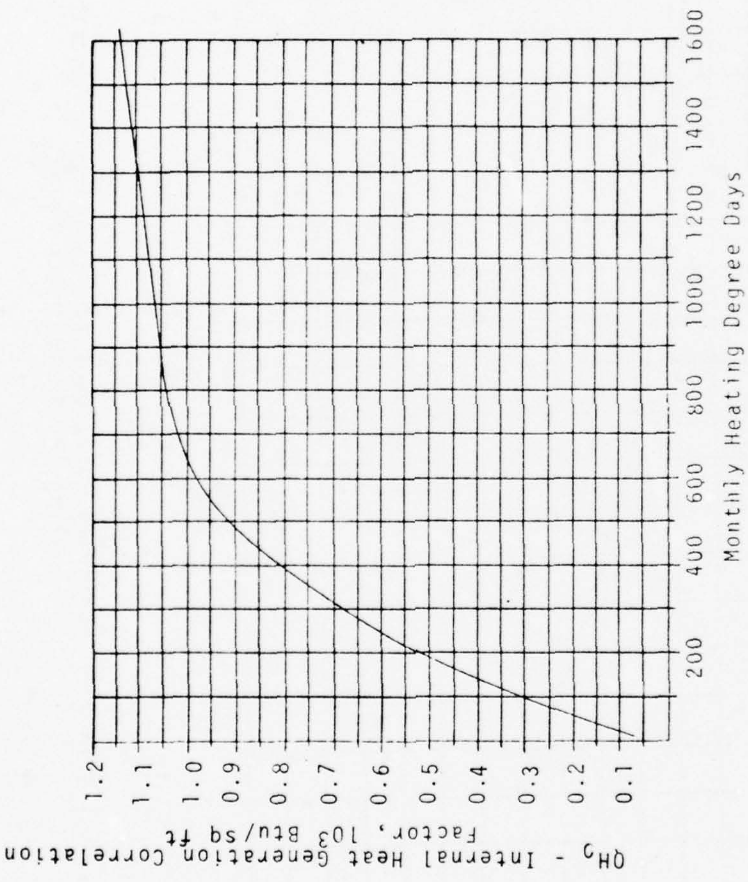


Figure 8-E. Internal Heating Load Correlation Factor During Heating Season As a Function of Heating Degree Days

COOLING
SINGLE-FAMILY

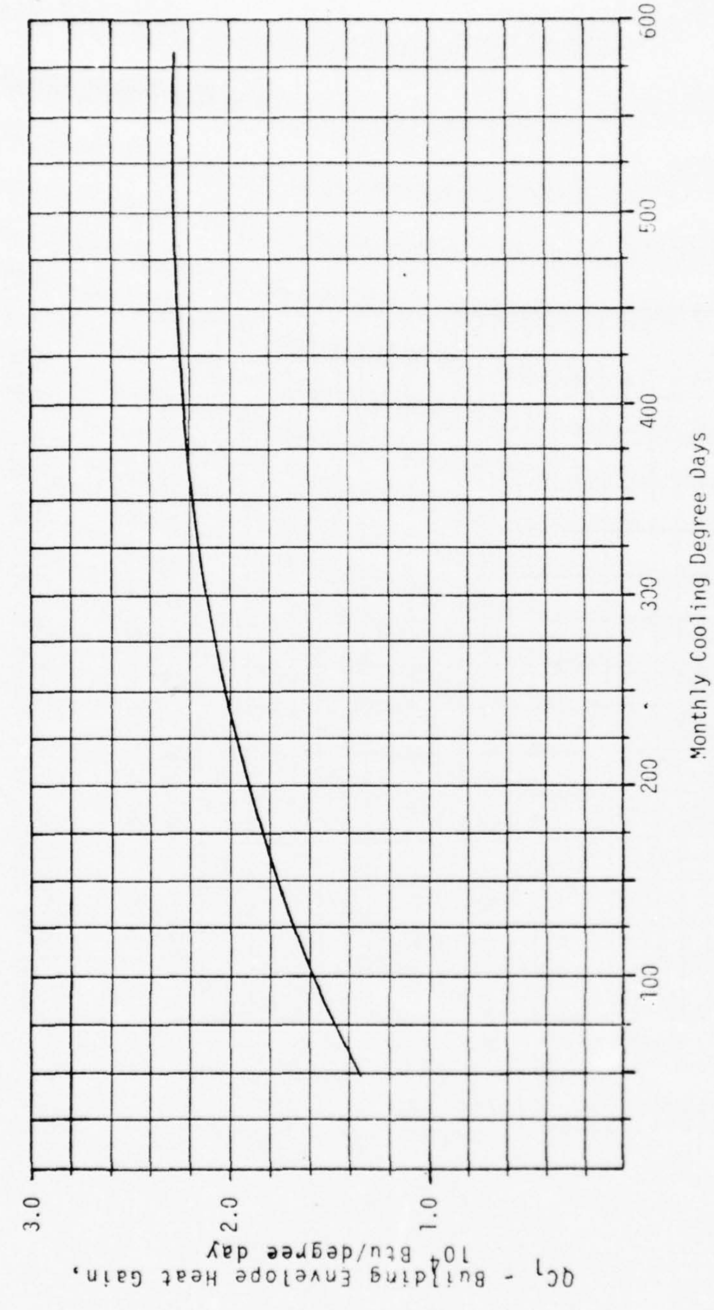


Figure 9-A. Building Envelope Cooling Load As a Function of Cooling Degree Days Per Month

COOLING

TOWN HOUSE

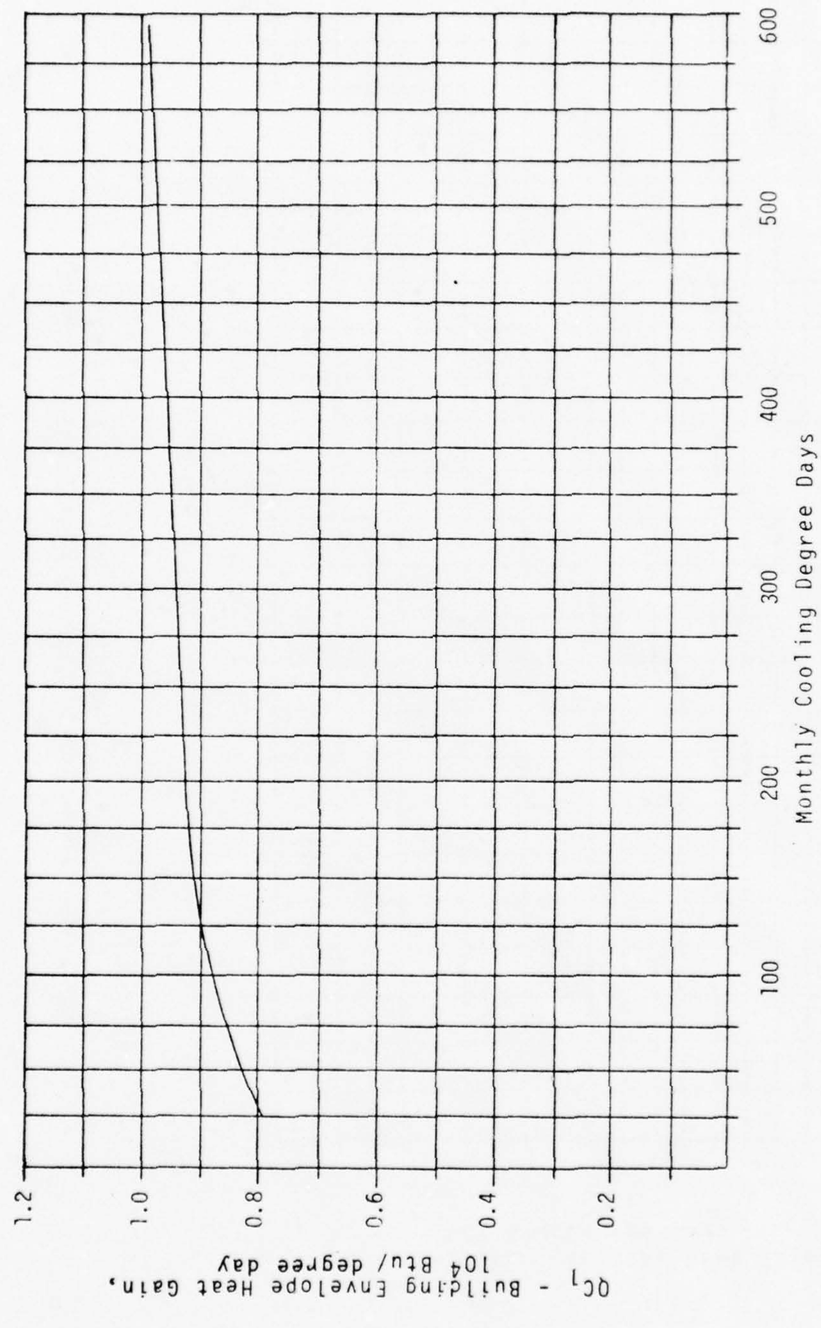


Figure 9-B. Building Envelope Cooling Load As A Function of Cooling Degree Days Per Month

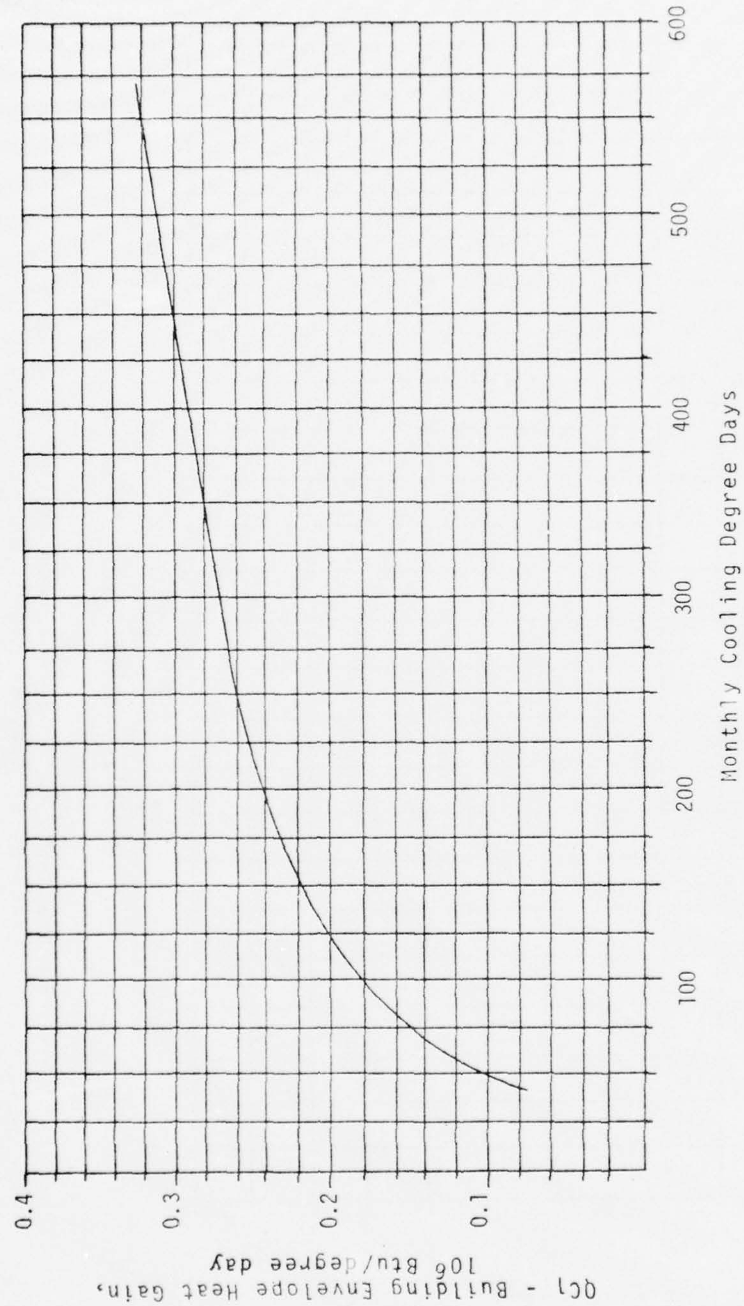


Figure 9-C. Building Envelope Cooling Load As a Function of Cooling Degree Days Per Month

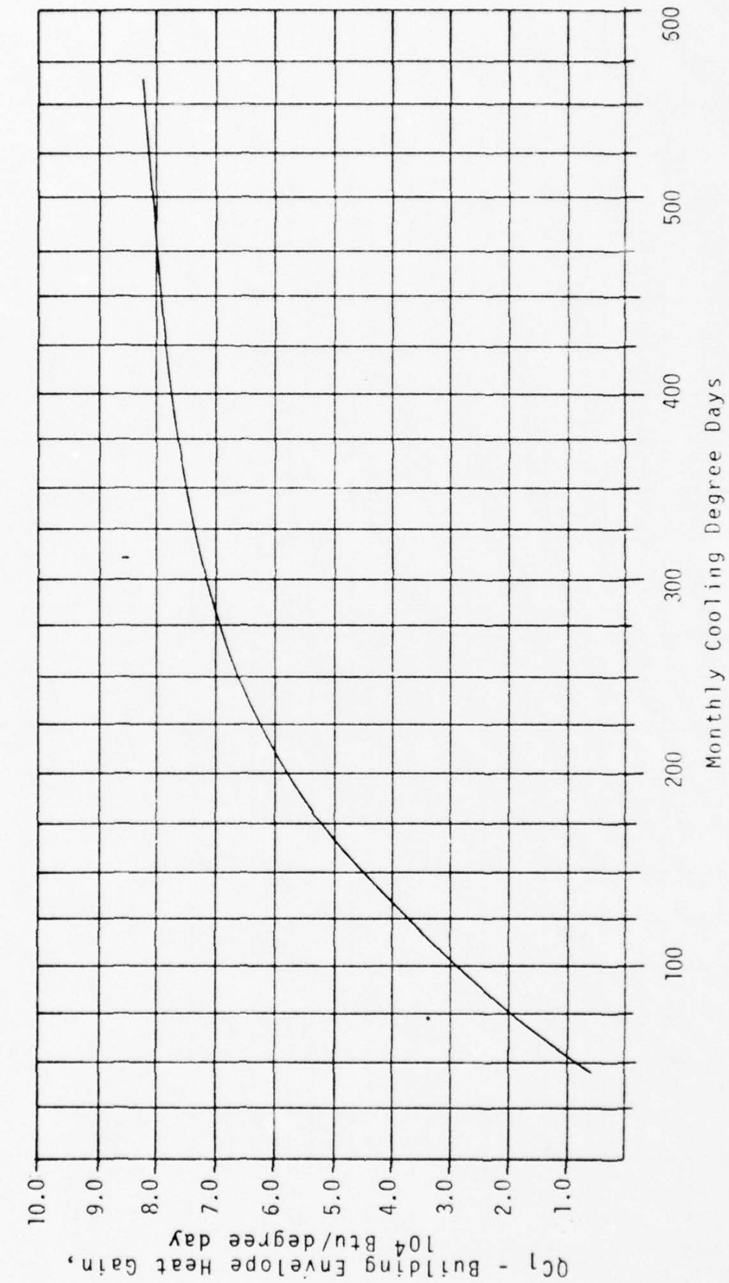


Figure 9-D. Building Envelope Cooling Load As a Function of Cooling Degree Days Per Month

COOLING

COMMISSARY

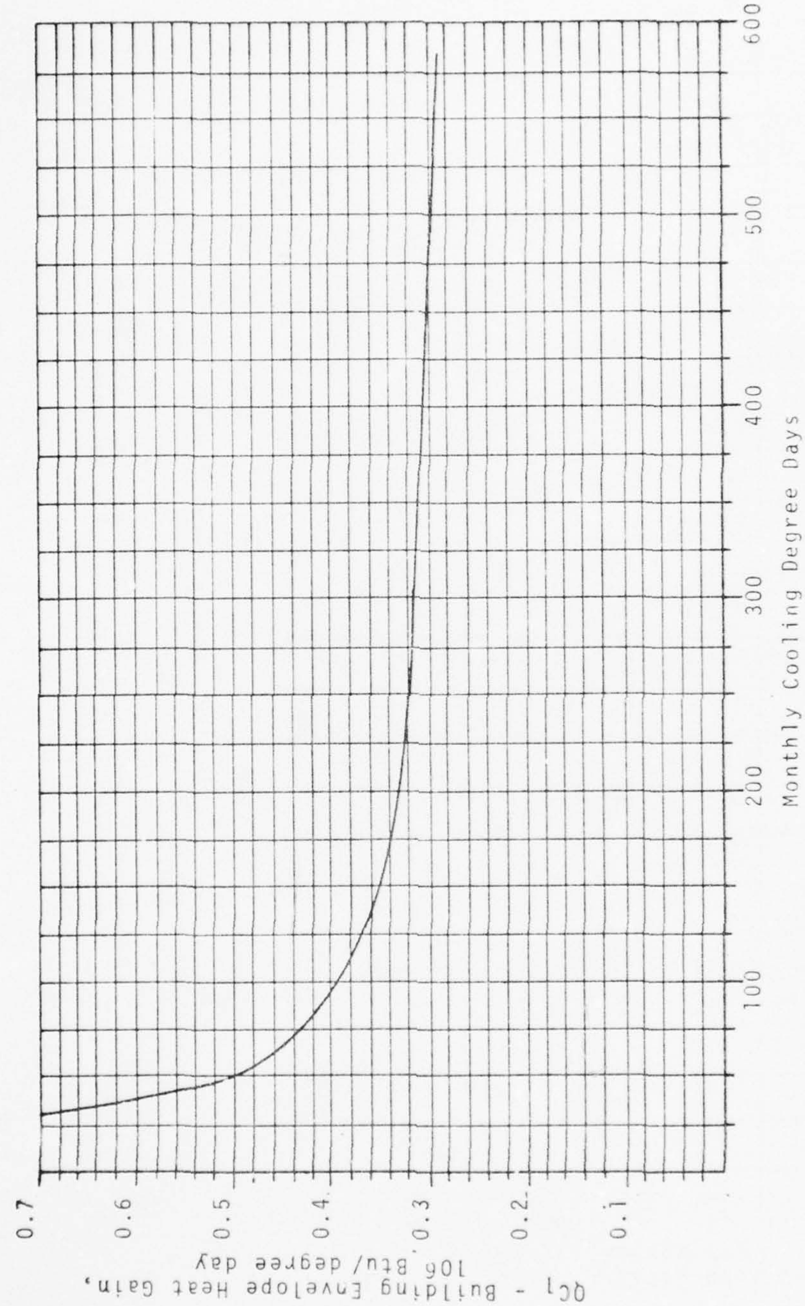


Figure 9-E. Building Envelope Cooling Load As a Function of Cooling Degree Days Per Month

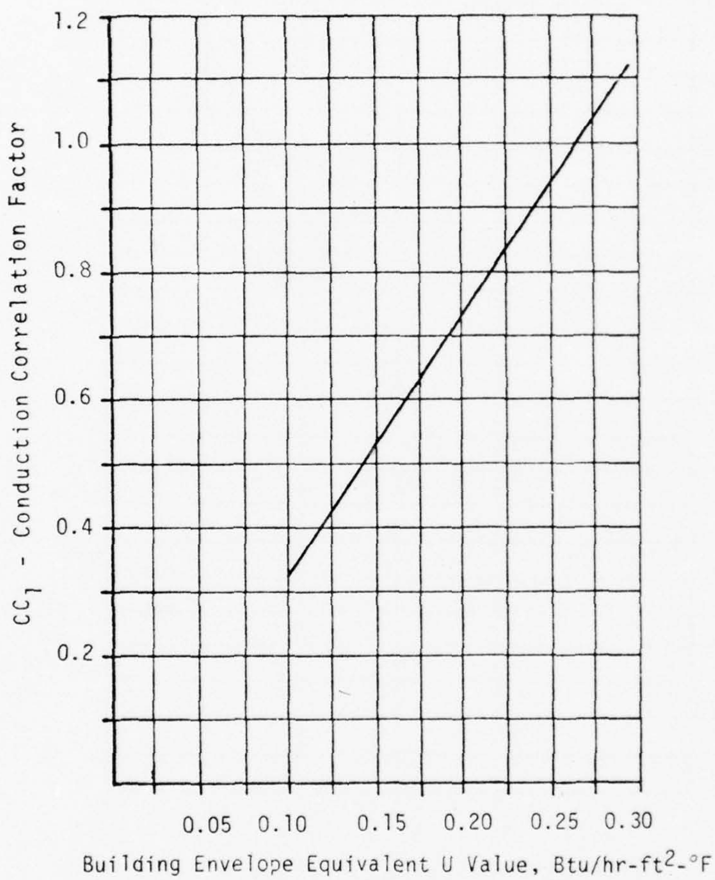


Figure 10-A. Building Envelope Cooling Load Correlation With Building Equivalent U Value

COOLING
TOWN HOUSE

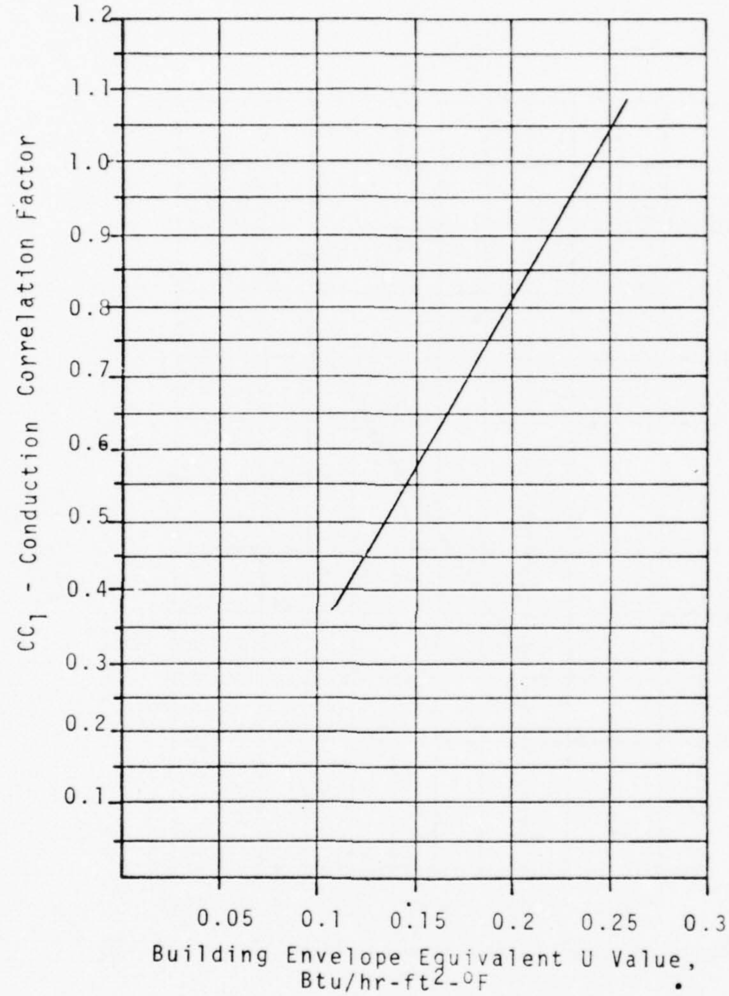


Figure 10-B. Building Envelope Cooling Load Correlation With Building Equivalent U Value

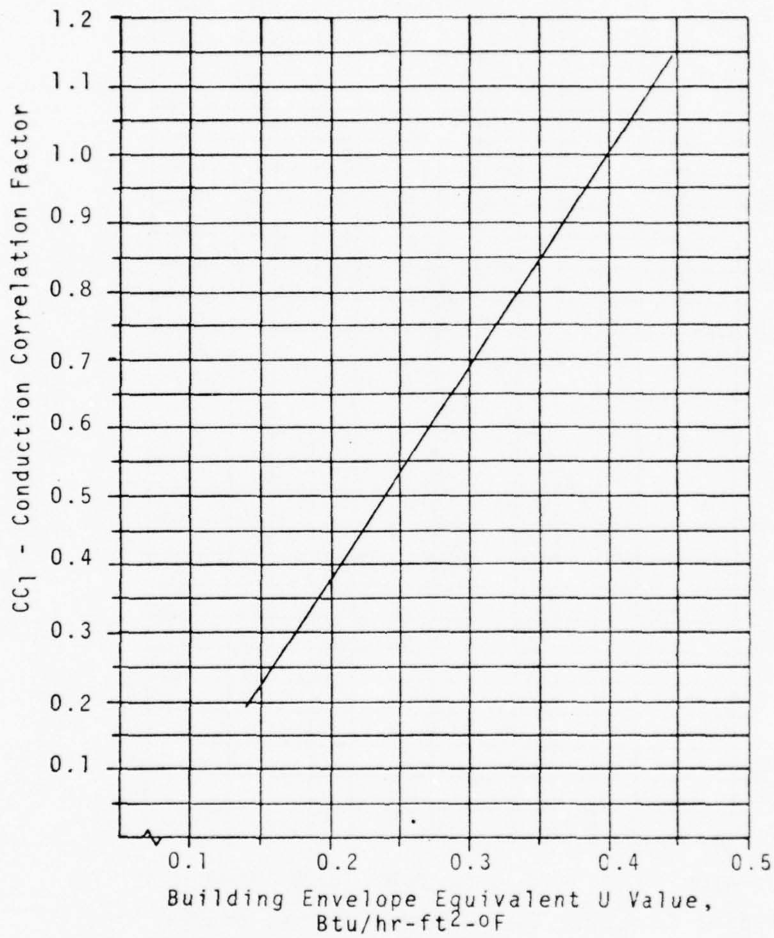


Figure 10-C. Building Envelope Cooling Load Correlation With Building Equivalent U Value

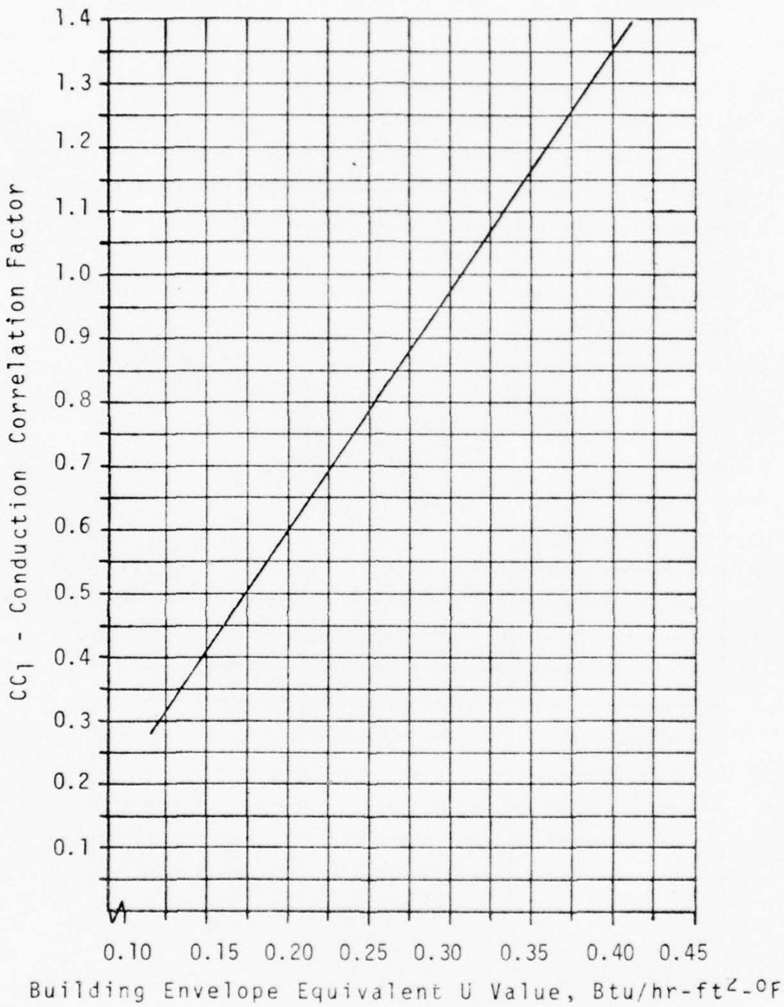


Figure 10-D. Building Envelope Cooling Load Correlation With Building Equivalent U Value

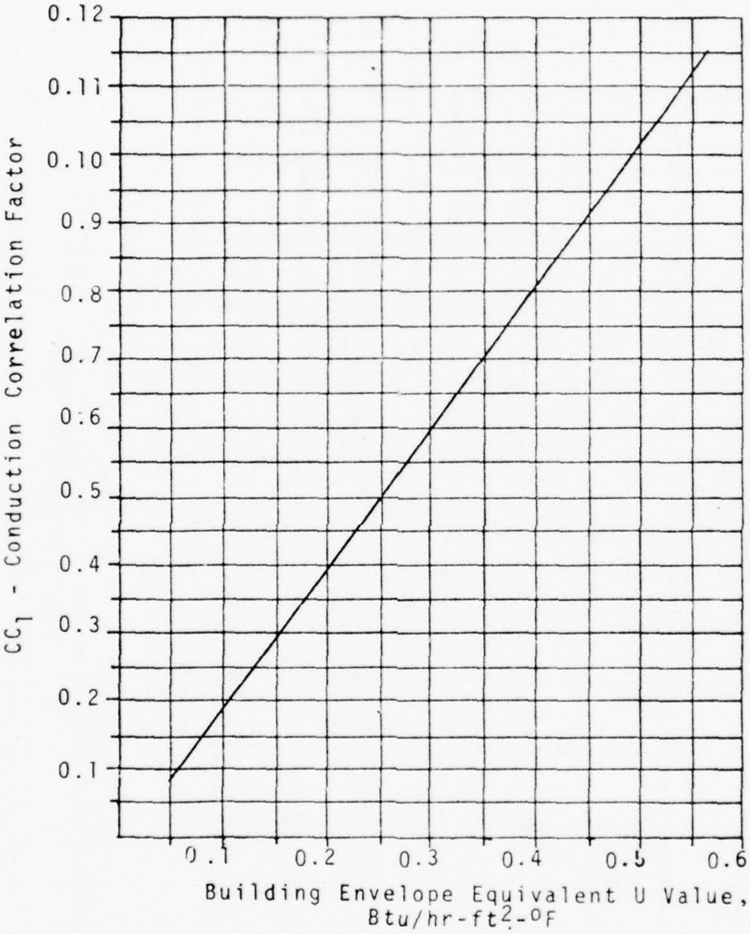


Figure 10-E. Building Envelope Cooling Load Correlation With Building Equivalent U Value

COOLING

SINGLE-FAMILY

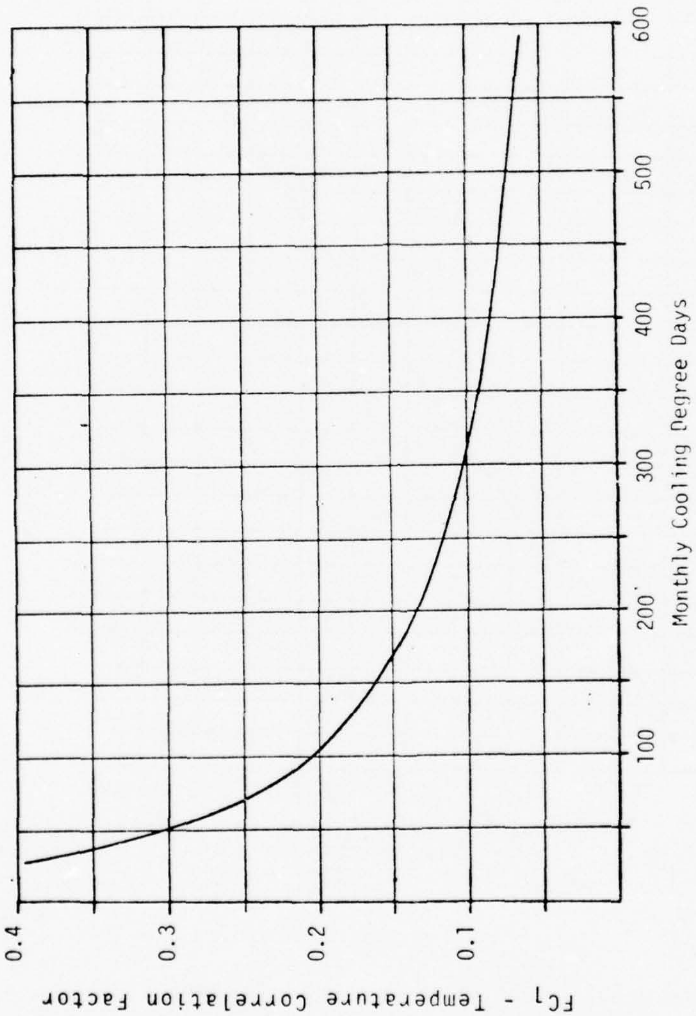


Figure 11-A. Building Envelope Cooling Load Correlation With Set-Point Temperature

COOLING

TOWN HOUSE

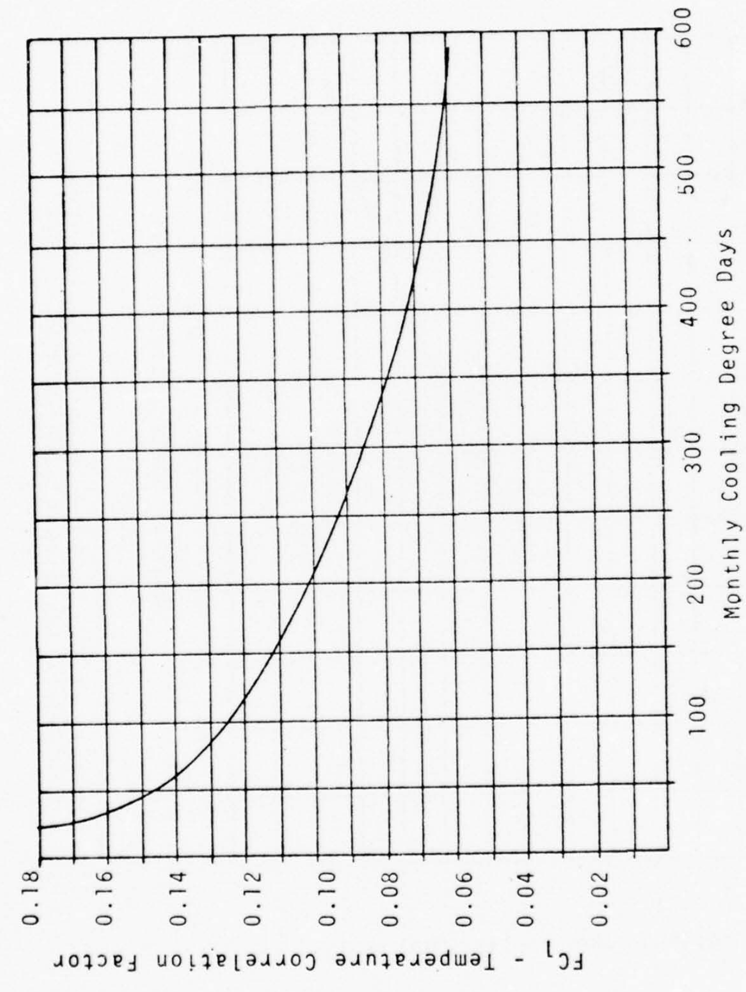


Figure 11-B. Building Envelope Cooling Load Correlation With Set-Point Temperature

COOLING BARRACKS

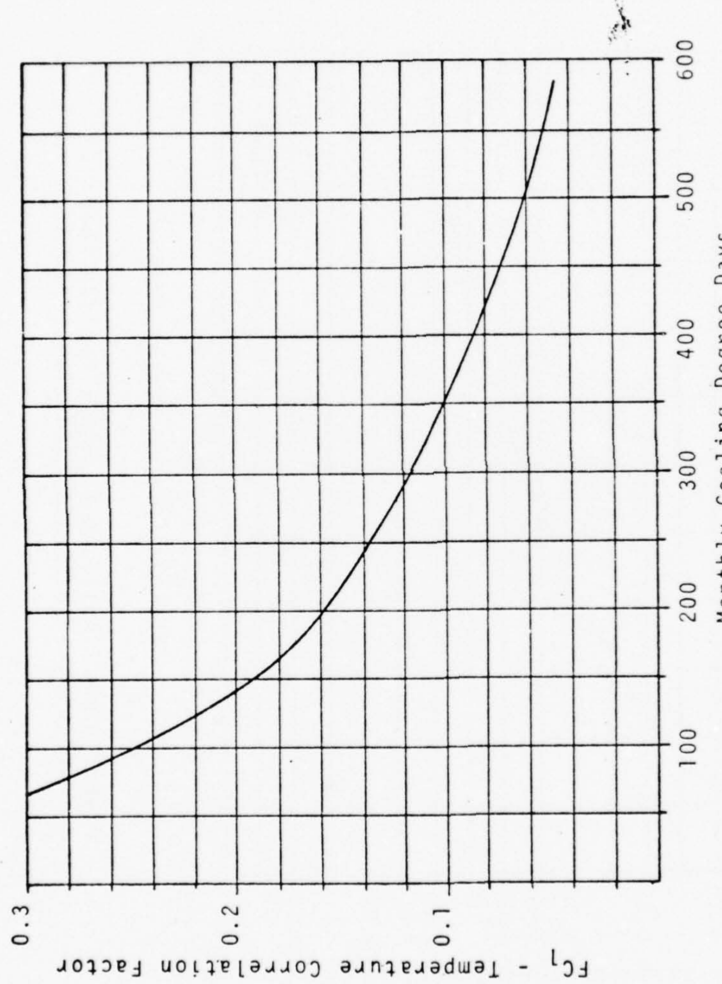


Figure 11-C. Building Envelope Cooling Load Correlation With Set-Point Temperature

COOLING

ADMINISTRATION

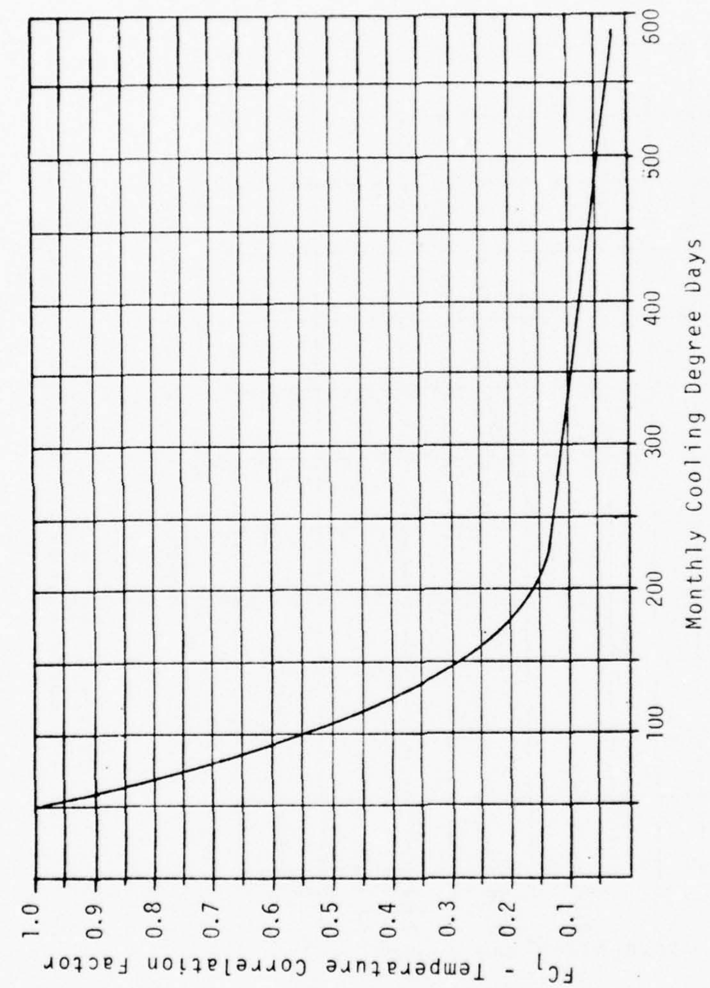


Figure 11-D. Building Envelope Cooling Load Correlation With Set-Point Temperature

COOLING COMMISSARY

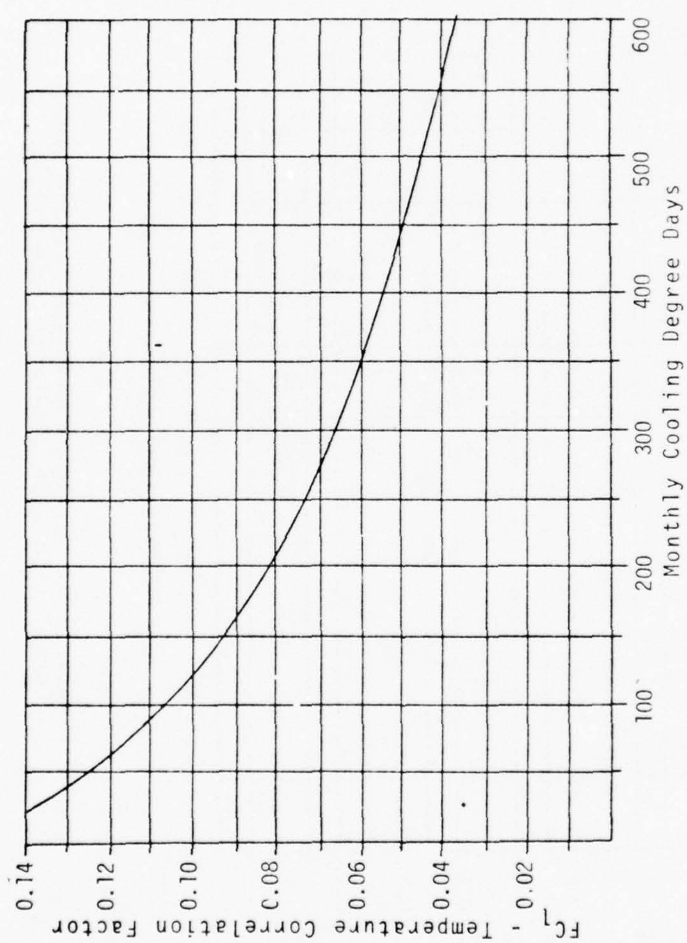


Figure 11-E. Building Envelope Cooling Load Correlation With Set-Point Temperature

COOLING

ALL BUILDINGS

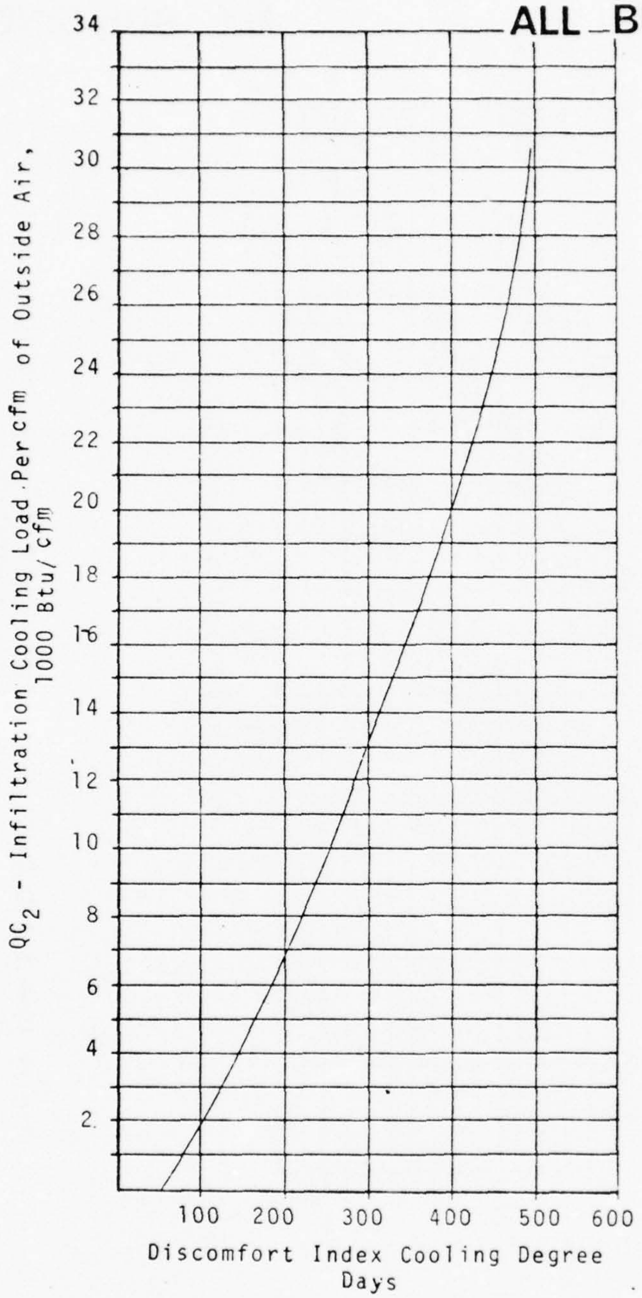


Figure 12-A,B,C,D,E. Infiltration Cooling Load As a Function of Discomfort Index Cooling Degree Days

COOLING
ALL BUILDINGS

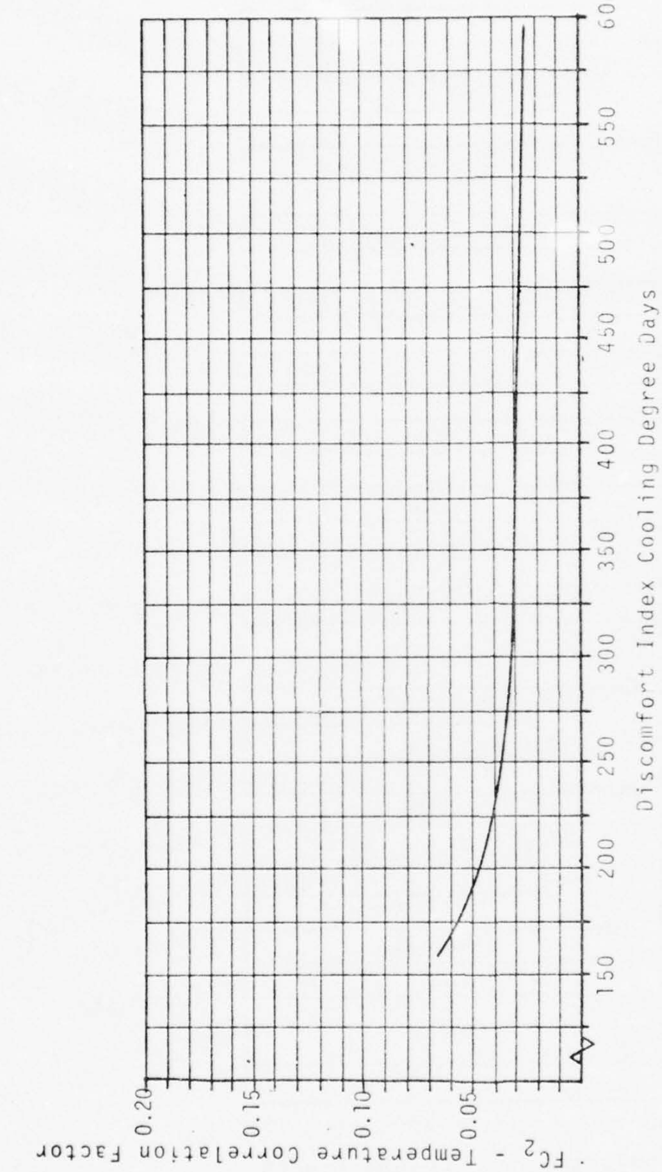


Figure 13-A,B,C,D,E, Infiltration Cooling Load Correlation With Set-Point Temperature

COOLING
SINGLE-FAMILY
TOWN HOUSE

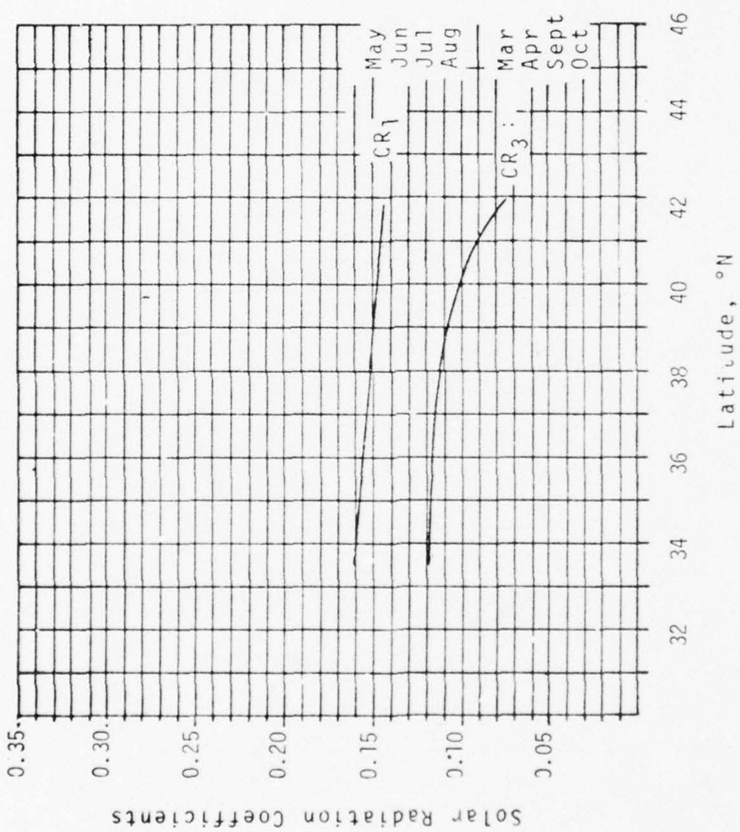


Figure 14-A,B.: Seasonal Solar Radiation Correlation Coefficients As a Function of Latitude

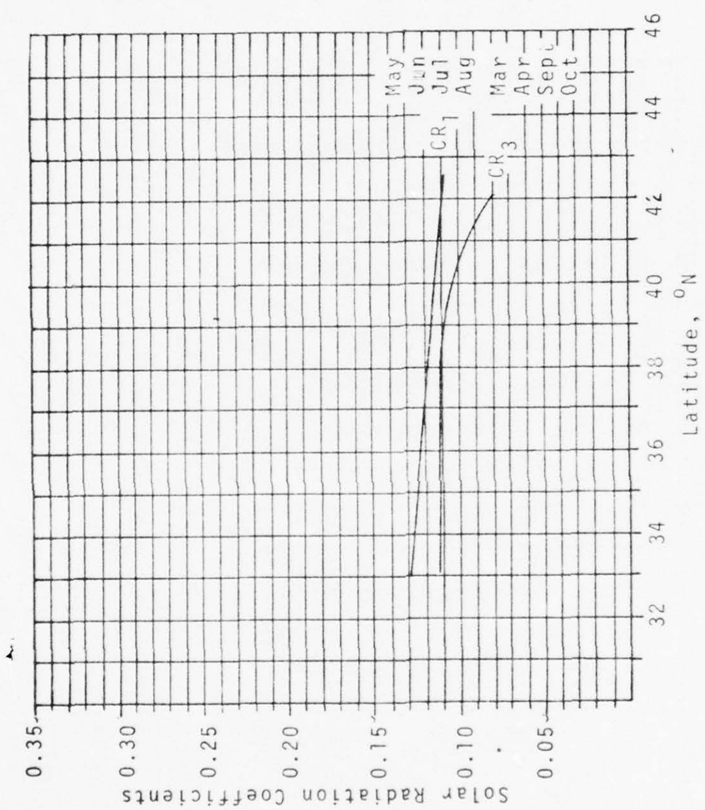


Figure 14-C. Seasonal Solar Radiation Correlation Coefficients As a Function of Latitude

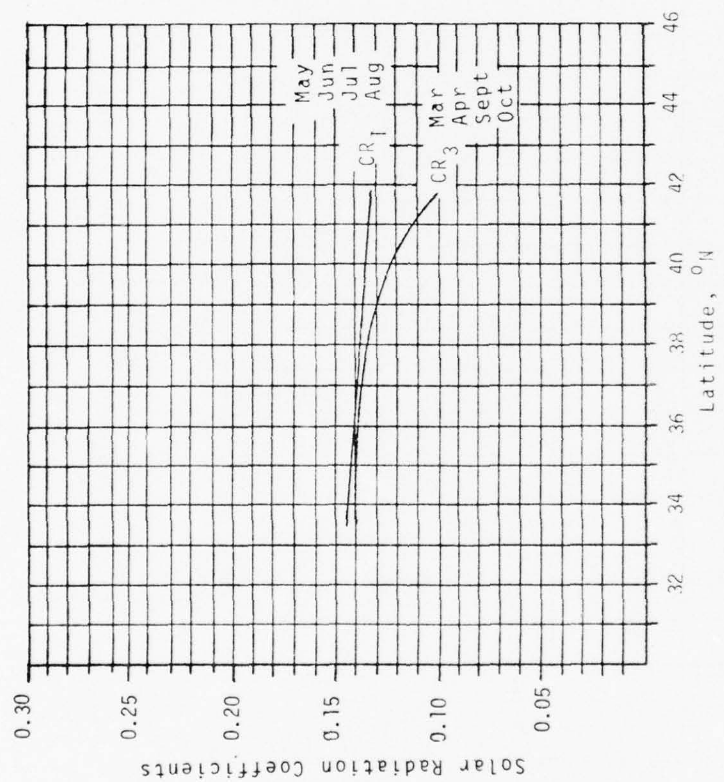


Figure 14-D. Seasonal Solar Radiation Correlation Coefficients As a Function of Latitude

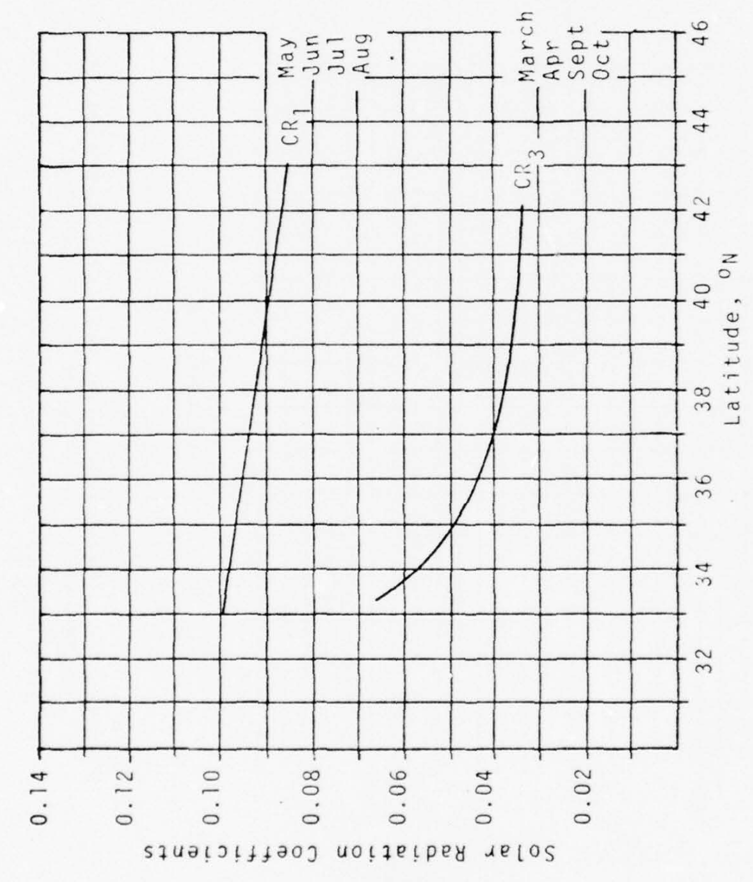


Figure 14-E. Seasonal Solar Radiation Correlation Coefficients As a Function of Latitude

COOLING
SINGLE-FAMILY
TOWN HOUSE
BARRACKS

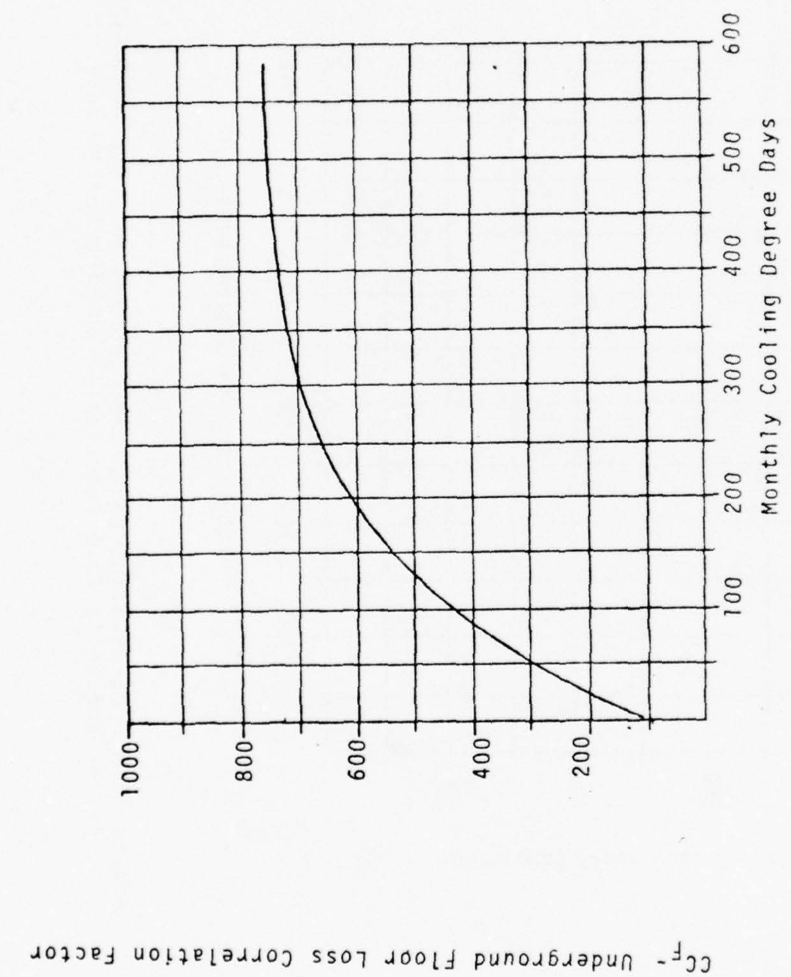


Figure 15-A,B,C. Correlation Factor for Cooling Load Due to Underground Floors and Walls As a Function of Cooling Degree Days

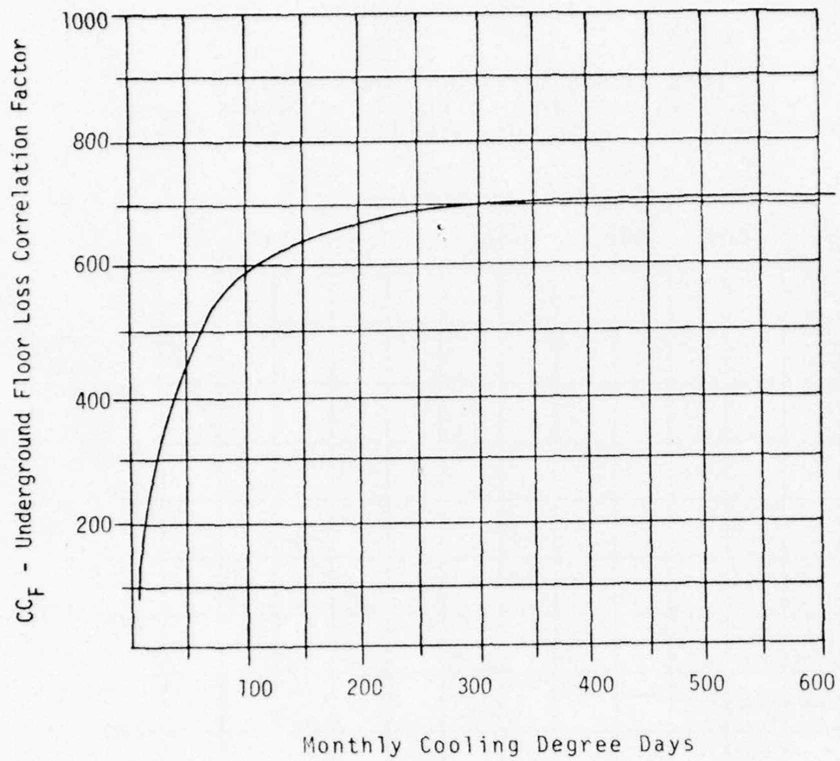


Figure 15-D. Correiation Factor for Cooling Load Due to Underground Floors and Walls As a Function of Heating Degree Days

COOLING
ADMINISTRATION

COOLING COMMISSARY

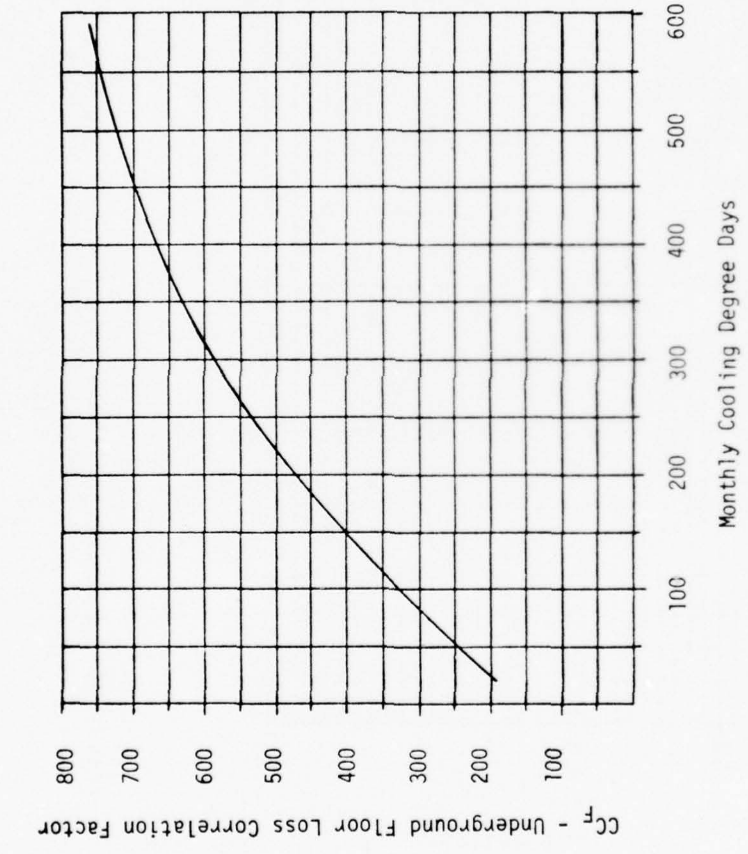


Figure 15-E. Correlation Factor for Cooling Load Due to Underground Floors and Walls As a Function of Heating Degree Days

COOLING

SINGLE-FAMILY TOWN HOUSE

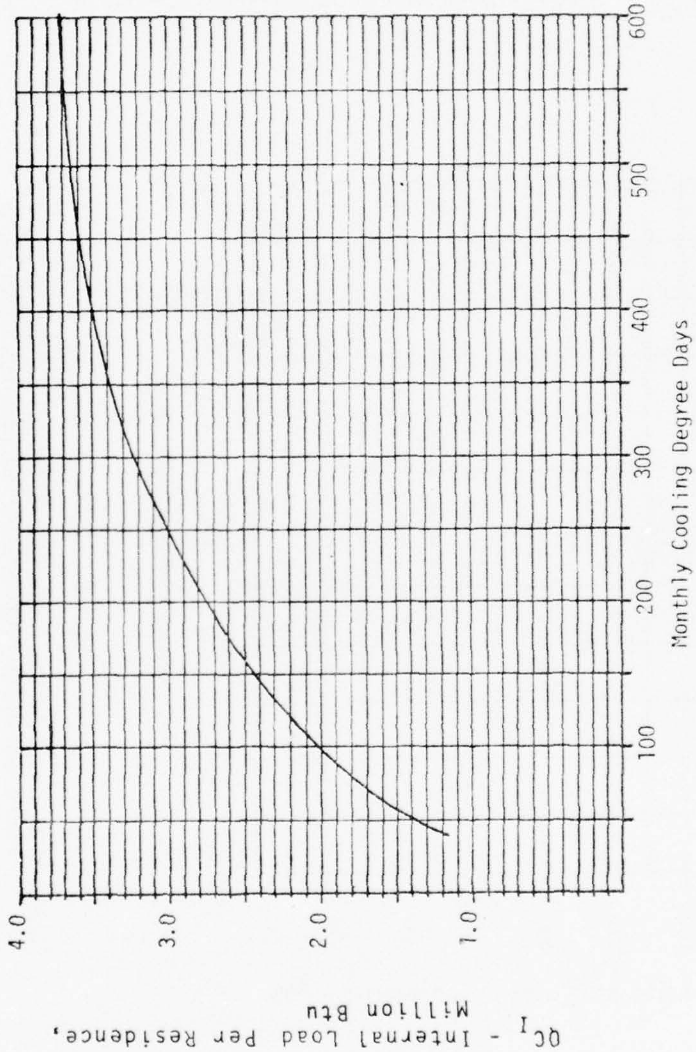


Figure 16-A,B. Internal Heat Generation During Cooling Season As a Function of Cooling Degree Days

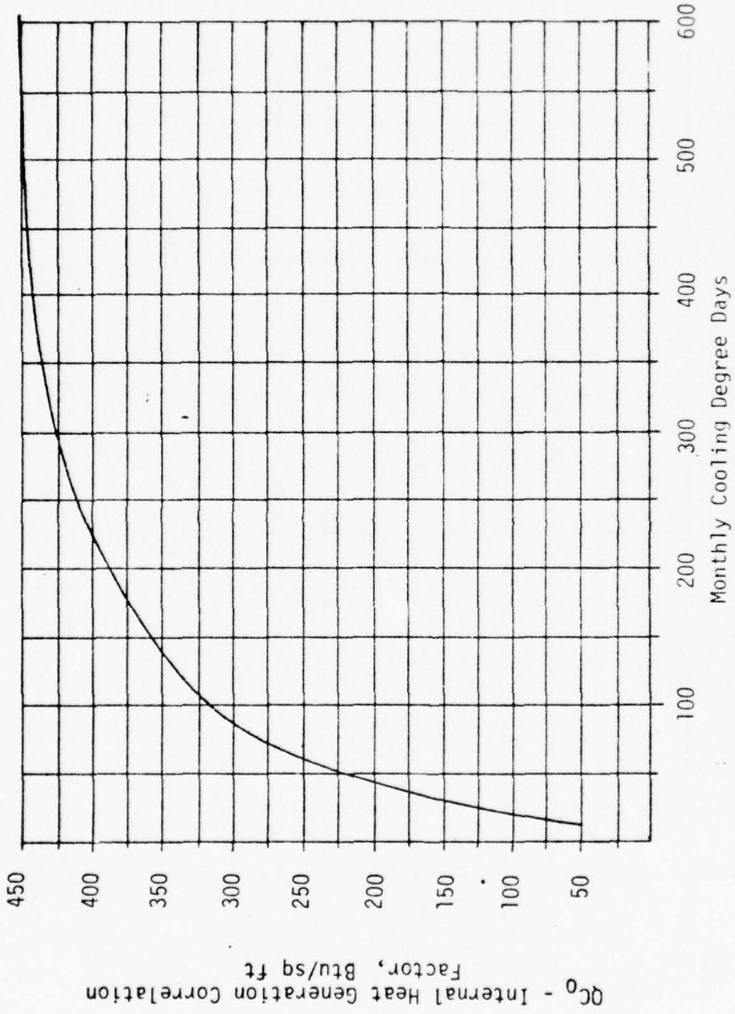


Figure 16-C. Internal Cooling Load Correlation Factor During Cooling Season As a Function of Cooling Degree Days

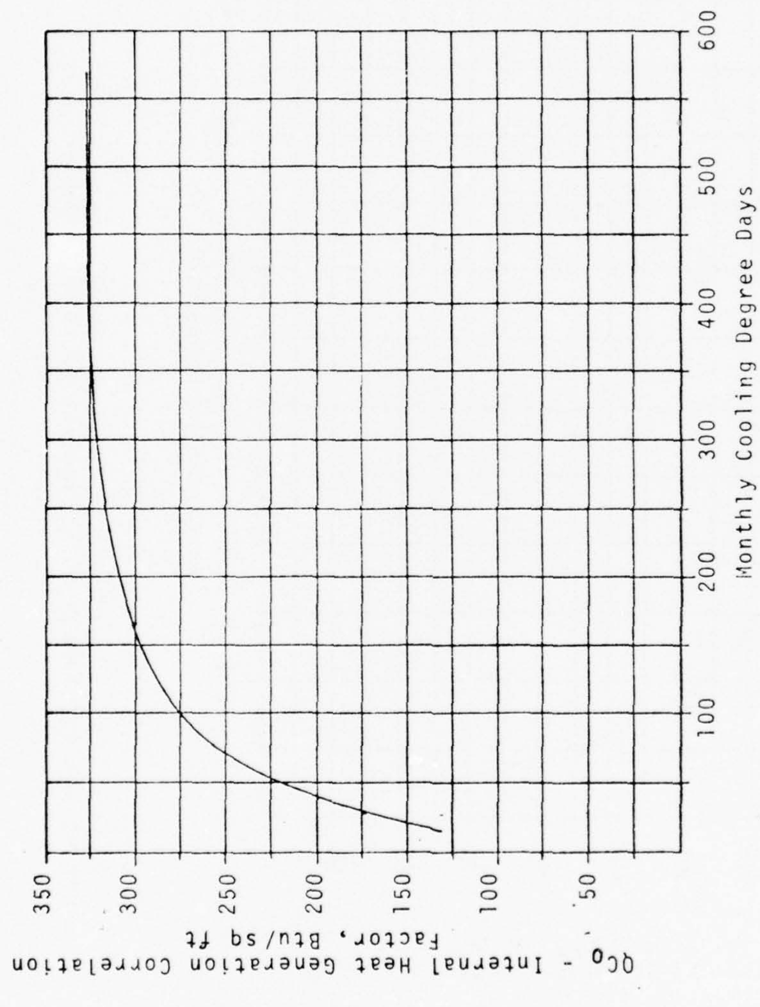


Figure 16-D. Internal Cooling Load Correlation Factor During Heating Season As a Function of Heating Degree Days

COOLING

COMMISSARY

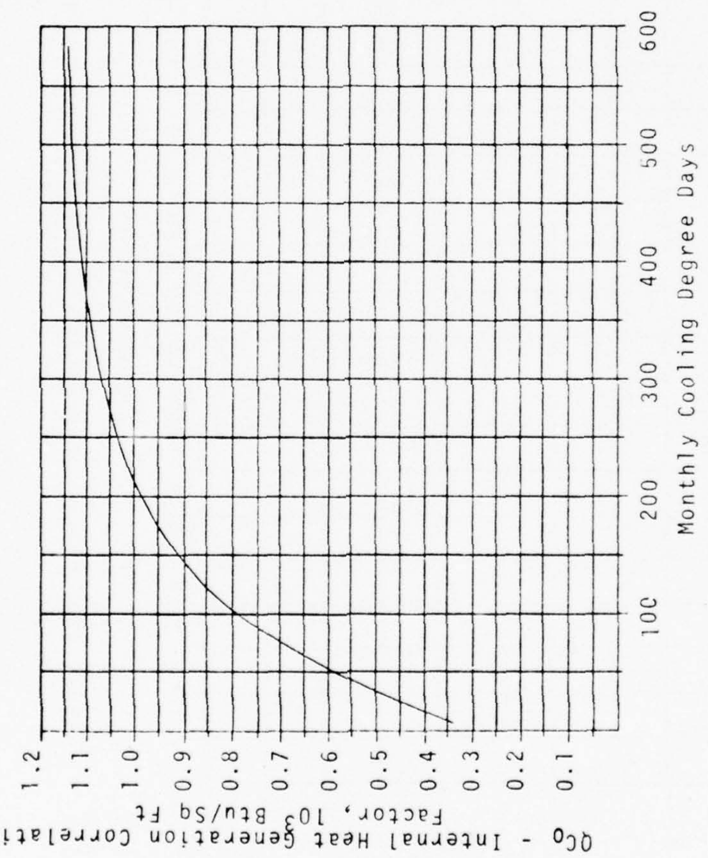


Figure 16-E. Internal Cooling Load Correlation Factor During Cooling Season As a Function of Cooling Degree Days

ALL BUILDINGS

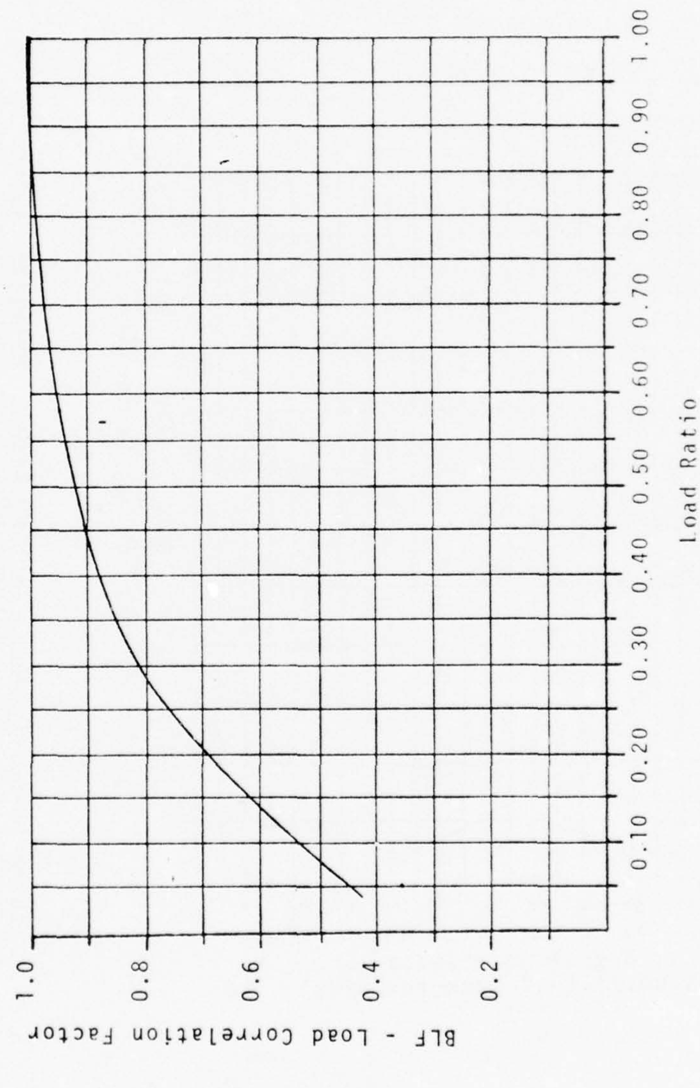


Figure 17. Boiler Load Factor As a Function of Load Ratio

ALL BUILDINGS

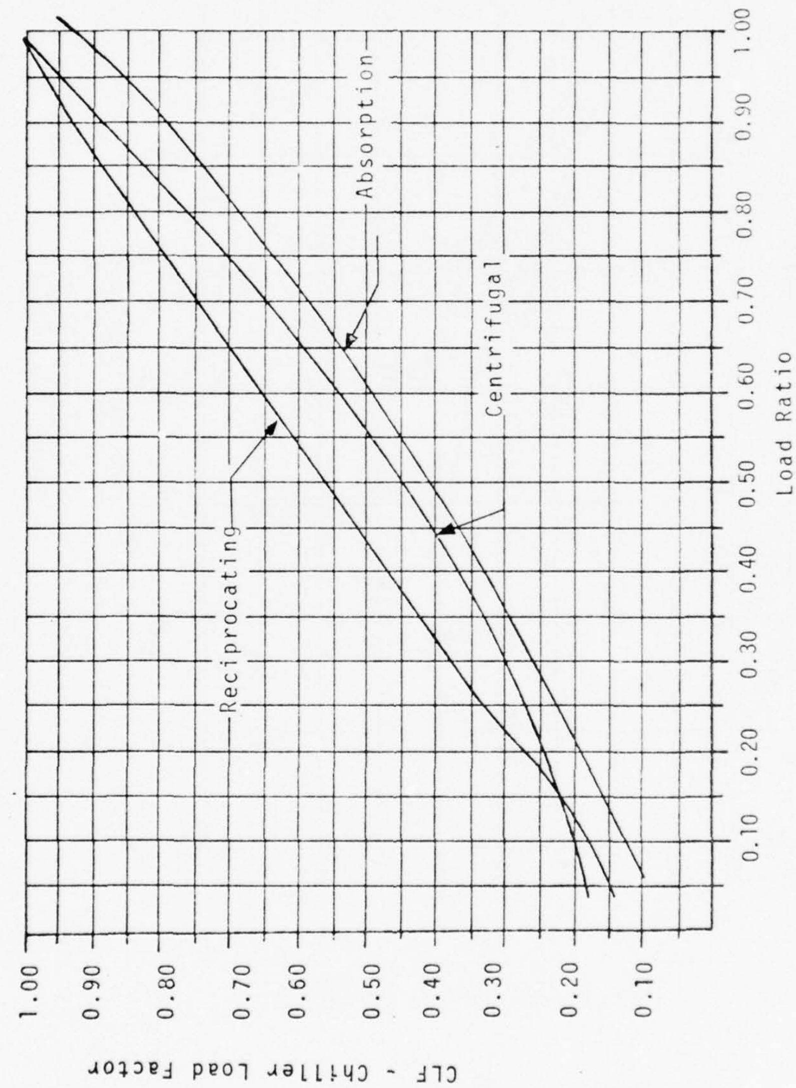


Figure 18. Chiller Load Factor As a Function of Load Ratio

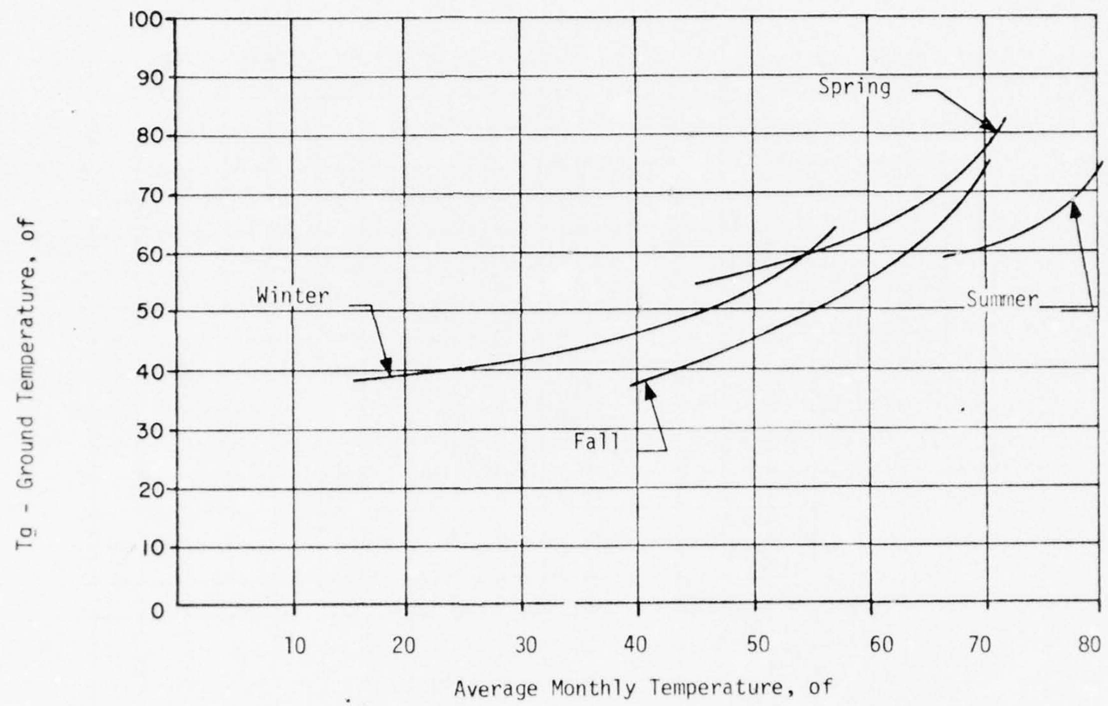


Figure 19. Ground Temperature as a Function of Average Monthly Temperature

APPENDIX A: Example Calculation

The following example provides step by step instructions for predicting the energy use of a building. Figure A1 shows a line drawing of the single-family unit chosen for this example. Tables A1, A2, and A3 provide tabularized forms for calculation of predicted energy use. Blank tables are provided for the user. These tables are designed so all known value can be placed on the table before calculations are begun.

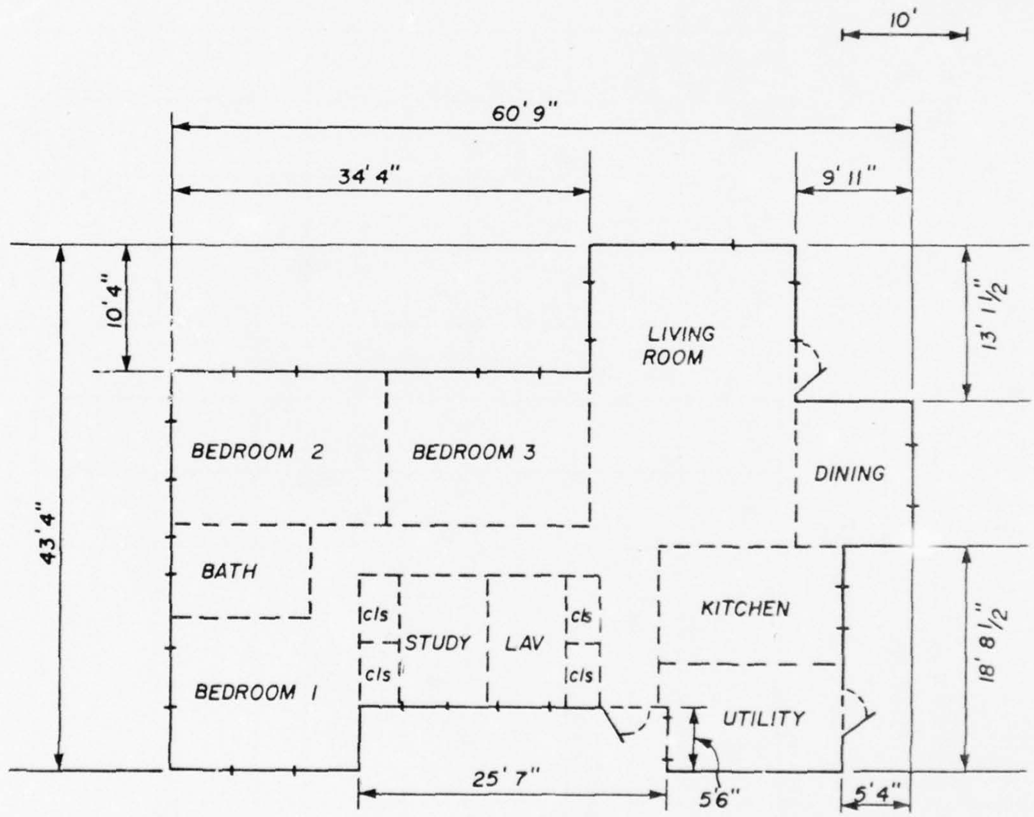


Figure A1. Buiding Sketch for Example Calculation

Table A1. HEATING ENERGY SUMMATION

Building______________________ Equivalent "U" Value______________________

Net Floor Area______________________ Volume______________________

Building Envelope Area______________________ Window Area______________________

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
(1) Heating Degree Days												
(2) QH_1												
(3) $CH_1 \times CON \times A_{total}$												
(4) FH_1												
(5) $1 + FH_1(T - 72)$												
(6) QH_{env} $(1 \times 10^4 \times 2 \times 3 \times 5)$												
(7) V (mph)												
(8) I (cfm)												
(9) QH_2												
(10) FH_2												
(11) $1 + FH_2\ (T - 72)$												
(12) $1 + V_r$												
(13) $QH_{inf}(9 \times 10^3 \times 11 \times 12)$												

Table A1 (cont)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
(14) $CR_{2,4}$												
(15) IR												
(16) Days (N)												
(17) $A_{WD} \times 3.687$												
(18) QH_{rad}(14x15x16x17)												
(19) $A_f U_f + A_w U_w$												
(20) CH_F												
(21) T_g												
(22) $(T - T_g)$												
(23) QH_{floor}(19x20x22)												
(24) QH_o												
(25) QH_I												
(26) WH_{total}(6+13-18+23-25)												
(27) QH_{heat}												

Table A2. COOLING ENERGY SUMMATION

Building__________ Equivalent "U" Value__________

Net Floor Area__________ Volume__________

Building Envelope Area__________ Window Area__________

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
(1) CDD's												
(2) QC_1												
(3) FC_1												
(4) $1 + FC_1(T-72)$												
(5) $A_t \times CC_1 \times K$												
(6) QC_{env} (1x2x4x5)												
(7) V												
(8) I												
(9) DICDD												
(10) QC_2												
(11) FC_2												
(13) $I + V_r$												
(14) QC_{inf}(10x12x13)												

Table A2 (Cont)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
(15) $CR_{1,3}$												
(16) IR												
(17) Days (N)												
(18) $A_t \times 3.687$												
(19) $QC_{rad}(15x16x17x18)$												
(20) CC_F												
(21) T_g												
(22) $T - T_g$												
(23) $A_fU_f + A_wU_w$												
(24) QC_{floor}20x22x23)												
(25) QC_o												
(26) QC_I												
(27) $QC_{total}(6+14+19-24-26)$ QC_{total}												
(28) $(1000)(EER)(E_{dist})$												
(29) Q_{cool} (kW-hr/mo)												

Example Calculation

(1) Determine the floor area of the building being analyzed (see Figure A1) or obtain from real property records.

Floor Area: 43 ft 4 in. x 60 ft 9 in. = 2632.5
Less:

a)	34 ft 4 in. x 10 ft 4 in.	=	354.8
b)	9 ft 11 in. x 13 ft 1 1/2 in.	=	130.2
c)	18 ft 8 1/2 in. x 5 ft 4 1/2 in.	=	100.6
d)	5 ft 6 in. x 25 ft 7 in.	=	140.7
			726.3

NET FLOOR AREA = 1906.2 sq ft

(2) Determine the Building Envelope Area (A_{total}) and volume

a) Wall Area = perimeter x height
= 219 ft 2 in. x 8 ft 0 in. = 1753.3
b) Roof Area = Floor Area = -1906.2

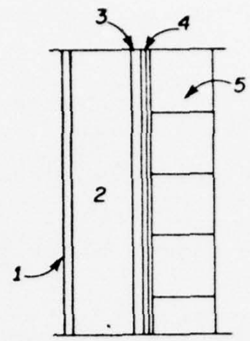
A_{total} 3659.5 sq ft

c) Volume = 1906.2 sq ft x 8 ft = 15,250 cu ft

(3) Determine the building envelope equivalent U value.

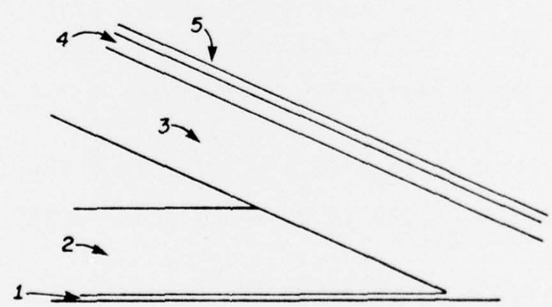
Exterior Surface	Area (sq ft)	U Value	Area x U Value
Roof (Figure A2)	1906.2	0.08	152.5
Wall (Figure A3)	1446.4	0.20	289.3
Windows	246.7	1.13	278.8
Doors	60.0	0.33	19.8
	3659.5		740.4

$$\text{Eq U} = \frac{740.4}{3695.5} = \underline{0.202}$$



1. ½" GYPSUM BOARD
2. 2" x 4" STUD, 16" o.c.
3. ¾" WOOD SHINGLE
4. #15 FELT
5. 4" FACE BRICK

Figure A2. Exterior Wall Construction



1. ½" GYPSUM BOARD
2. 2" x 6" JOIST AT 16" o/c. FILLED WITH BATT. INSULATION
3. 2" x 6" RAFTERS AT 16" o/c.
4. ¾" SHEATHING
5. COMPOSITE ROOFING

Figure A3. Ceiling-Roof Construction

(4) Obtain the monthly heating degree days (HDD) for the location and enter in row 1 of Table A1.

(5) Using the HDDs, determine QH_1 from Figure A1 and enter in row 2 of Table A1.

(6) Determine CH_1 from Figure A2 for the U factor previously calculated.

$$U = 2.202, \; CH_1 = 0.765$$

(7) CON x A_{total} x CH_1, is constant; enter in row 3 of Table A1: (2.246×10^{-4}) (3659.5 (0.765) = 0.63

(8) Find FH_1 for each month's HDD from Figure A3 and enter in row 4.

(9) Determine total set point correction for each month and enter in row 5: $1 + FH_1\ (70-72) = 1 - 2\ (.09) = 0.82$ (Sept).

(10) Determine QH_{env} by multiplying the numbered values on Table A1 as shown below and enter result in row 6.

$$QH_{env}\ (1)\ (2)\ (3)\ (5)$$
$$= (132)\ (40 \times 10^3)\ (.629)\ (0.82)$$
$$= 2.72 \times 10^6 \text{ Btus (Sept)}$$

(11) Determine the infiltration coefficient A for single-family residence:

$$A = 0.25\ (N_o)\ (S_1) + 7.7 \times 10^{-3}\ (Aw)\ (S_2)$$
$$A = 0.25\ (3)\ (1.0) + 7.7 \times 10^{-3}\ (247)\ (1.0)$$
$$= 2.65$$

(12) Enter average wind velocity (V) in row 7.

(13) Determine the infiltration rate, I, and enter in row 8. Note that I will change when the average wind velocity, V, changes.

$$I = [0.25 + (0.037)\ (A)\ (V)]\ \frac{\text{volume}}{60}$$

$$I = [.25 + (0.037)\ (2.65)\ (10)]\ \frac{15250}{60} = 312.7$$

(14) Find QH_2 for each month's HDDs from Figure A4 and enter in row 9.

(15) Find FH_2 for each month's HDDs from Figure A5 and enter in row 10.

(16) Calculate set-point correction factor for each month and enter in row 11. $1 + FH_2\ (70-72) = 1 + .085\ (-2) = 0.830.$

(17) Determine the outside air intake rate, V_r, and add to I. (In this example $V_r = 0$.) Enter in row 12.

(18) Determine QH_{inf} by multiplying the values on Table A1 as shown below and enter result in row 13.

$$QH_{inf} = (9)\ (11)\ (12) = (6.9 \times 10^3)\ (0.83)\ (313)$$
$$= 1.79 \times 10^6 \text{ Btus (Sept).}$$

(19) Find $CR_{2,4}$ from Figure A6 for the location and month and enter in row 14.

(20) Find the average daily solar radiation for the location nearest the building from Table 1 and enter in row 15.

(21) Enter number of days in each month in row 16. For each month, multiply the area of windows by the constant (3.687) and enter in row 17.

(22) Determine QH_{rad} for each month by multiplying the values in Table A1 as shown below and enter result in row 18.

$$QH_{rad} = (14)\ (15)\ (16)\ (17)$$

$$QH_{rad} = (.092)\ (412)\ (30)\ (910) = 1.035$$
$$\times 10^6 \text{ Btus (Sept).}$$

(23) Calculate $[(A_f)\ (U_f) + (A_w)\ (U_w)]$ and enter in row 19.

$$[(1906.2)\ (0.1) + (0.0)(0.0)] = 190.6$$

(24) Determine CH_f from Figure A7 using monthly HDD, and enter in row 20.

(25) Find average monthly ground temperatures (Table A2 and Figure 19) and enter in row 21.

(26) Compute (T-Tg) and enter in row 22.

(27) Determine QH_{floor} for each month by multiplying the values in Table A1 as shown below and enter in row 23.

$$QH_{floor} = (19)(20)(22) = (190.62)(.32 \times 10^3)(12)$$
$$= 0.732 \times 10^6 \text{ Btus (Sept).}$$

(28) Determine QH_I from Figure 8 using monthly HDDs, and enter in row 25.

$$QH_I = 1.560 \times 10^6 \text{ Btus (Sept)}.$$

(29) Determine the total heating load, QH_{TOTAL}, by adding and subtracting the monthly values in Table A1, as shown below:

$$\begin{aligned} QH_{TOTAL} &= (6) + (13) - (18) - (25) + (23) \\ &= (2.723 \times 10^6) + (1.791 \times 10^6 - (1{,}034.8 \times 10^6) \\ &- (1.560 \times 10^6) + (.732 \times 10^6) \\ &= 2.651 \times 10^6 \text{ Btus (Sept)}. \end{aligned}$$

(30) Determine the heating energy use, Q_{HEAT}, by dividing Q_{TOTAL} by E_f and E_{dist}. Enter in row 27 of Table A1 and column 1 of Table A3.

$$Q_{HEAT} = \frac{2.651 \times 6 \times 10^6}{(.75)\ (0.90)} = 3{,}928.3 \times 10^6 \text{ Btus (Sept)}.$$

Cooling

Obtain the monthly cooling degree days (CDD) for the location and enter in row 1 of Table A2.

(2) Using the CDDs, determine QC_1 from Figure A9 and row 2 of Table A2.

(3) Determine FC_1 from Figure 11 and enter in row 3.

(4) Determine the set point correlation for each month and enter in row 4. $1\text{-}FC_1\ (70\text{-}72) = 1\text{-}(-2)\ (.183) = 1.366$

(5) Find CC_1 from Figure 10A for the U factor previously calculated.

$A_{total} \times CC_1 \times K$ is constant for each month. Calculate and enter in row 5 of Table A2.

(6) Determine QC_{env} by multiplying the values on Table B, and enter these results in row 6.

$$\begin{aligned} QH_{env} &= (1)(2)(4)(5) \\ &= (126)\ (16.9 \times 10^3)(1.366)(0.596) \\ &= 1.73 \times 10^6 \text{ Btus (June)} \end{aligned}$$

(7) Enter average wind velocity (V) in row 7.

(8) Determine the infiltration ratios, I, and enter in row 8. (Described in heating section.)

(9) Determine the Discomfort Index CDD (DICDD) from Table 4 and enter in row 9.

(10) Find QC_2 from Figure 12 using monthly DICDD, and enter in row 10.

(11) Determine FC_2 from Figure 13 using DICDD, and enter in row 11.

(12) Compute set-point correlation factor for each month and enter in row 12.

$$1-FC_2(T-72) = 1-(-2)(0.5) = 1.10.$$

(13) Add the outside air intake rate to I and enter in row 13.

(14) Determine QC_{inf} by multiplying the values in Table A2 as shown below and enter results in row 14.

(15) Find $CR_{1,3}$ from Figure 14 for the location and enter in row 15.

(16) Find the average daily solar radiation for the location nearest the building for Table 1, and enter in row 16.

(17) Enter the number of days in each month in row 17.

(18) For each month multiply the area of windows by the constant 3.687 and enter in row 18.

(19) Determine QC_{rad} for each month by multiplying the value in Table A1 as shown below and enter result in row 19.

$$QC_{rad} = (15)(16)(17)(18)$$
$$= (0.15)(525)(30)(910) = 2.15 \times 10^6 \text{ Btus (June)}$$

(20) Determine CC_f from Figure 15 using CDD, and enter these values in row 20.

(21) Find Tg for the location, and enter in row 21.

(22) Compute (T-Tg) and enter in row 22.

(23) Calculate $[(A_f)(U_f) + (A_w)(U_w)]$, and enter in row 23.

(24) Determine QC_{floor} for each month by multiplying the values in Table A2 as shown below, and enter in row 24.

$$QC_{floor} = (20)(22)(23) =$$

$$= (499)\ (8)\ (190.6) = 0.76 \times 10^6 \text{ Btus (June)}$$

(25) Determine QC_I from Figure 16 using monthly CDD, and enter in row 26.

$$QC_I = 2.24 \times 10^6 \text{ Btus (June)}$$

(26) Determine the total cooling load, QC_{TOTAL}, by adding and subtracting the monthly values in Table A2, as shown below.

$$QC_{TOTAL} = (6) + (14) + (19) - (24) + (26)$$

$$= (1.73 \times 10^6) + (2.414 \times 10^6) + (2.15 \times 10^6)$$

$$- (.761 \times 10^6) + (2.240 \times 10^6) = 7.77 \times 10^6 \text{ Btus (June)}$$

(27) Determine the cooling energy use, Q_{cool}, by dividing QC_{TOTAL} by (1000), EER, and $E_{dist.}$ as shown below.

$$Q_{COOL} = \frac{7.77 \times 10^6}{(1000)(6.0)(0.9)} = 1425.9 \text{ Kw-Hr (June)}$$

Lighting

Determine lighting energy using the factor from Section IV of this manual and multiplying times number of days in the month and building floor area; enter the results in Column 3 of Table A3.

3.23×10^{-3} Kw-hr/sq ft/day x 31 days x 1906 sq ft

= 192. Kw-hr/month.

Cooking

Determine cooking energy by using the factor from Section V of this manual for natural gas range and multiplying by number of days in the month. Enter in Column 4 of Table A3 .

2.9×10^4 Btu/day x 31 = 0.9×10^6 Btus/month.

Hot Water Heating

Determine the domestic hot water heating energy, using the factor from Section VI of the manual for a gas water heater with pilot and multiplying by the number of days in the month. Enter in Column 5 of Table A3.

75,000 Btus/day x 31 days = 2.32×10^6 Btus/month

Laundry

Determine the laundry energy use from Section VII and enter in Column 6 for automatic washing machine and electric dryer.

0.3 Kw-hr/day x 31 days =	9.3 Kw-hr/month
2.7 Kw-hr/day x 31 days =	83.7 Kw-hr/month
	93 Kw-hr/month

Appliances

Determine the electrical equipment and appliance energy use from Section IX and enter in Column 8.

Basic appliance	8.2 Kw-hr/day
Color TV	1.4
Dishwasher	1.0
Humidifier	1.0
Furnace fan	1.1
	12.7 Kw-hr/day x 31 days = 393 Kw-hr/month

Table A3. RECOMMENDED TABLES FOR BUILDING ENERGY SUMMATION

Building No. _____

Month	Q_{heat}	Q_{cool}	Ltgt	Cooking	DHW	Lndy	CdST	Eq/AP	Addl	TOTAL
JAN										
FEB										
MAR										
APR										
MAY										
JUN										
JUL										
AUG										
SEP										
OCT										
NOV										
DEC										
TOTAL										

	Fuel Source							
Activity	Electricity	Oil	Gas	Steam	Hot Water	Chilled Water	Coal	Other
Q_{heat}								
Q_{cool}								
Ltgt								
Cooking								
DHW								
Lndy								
CdST								
Eq/AP								
Addl								
TOTAL								

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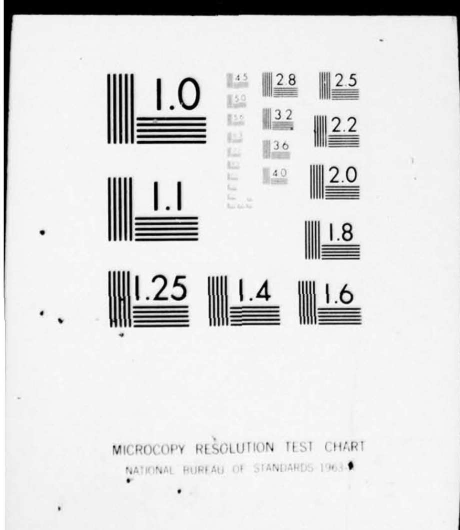

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